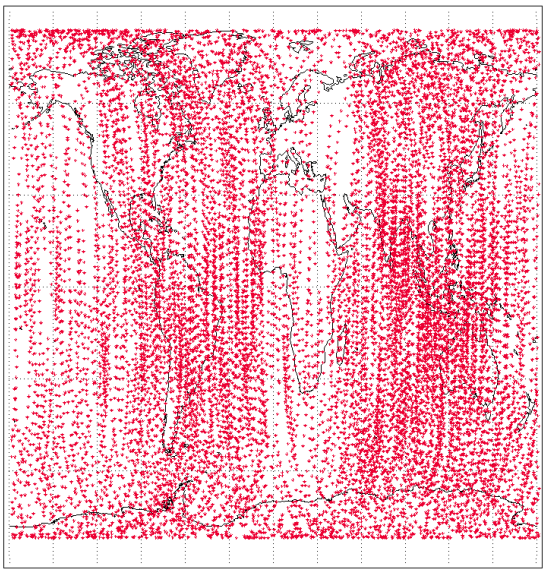
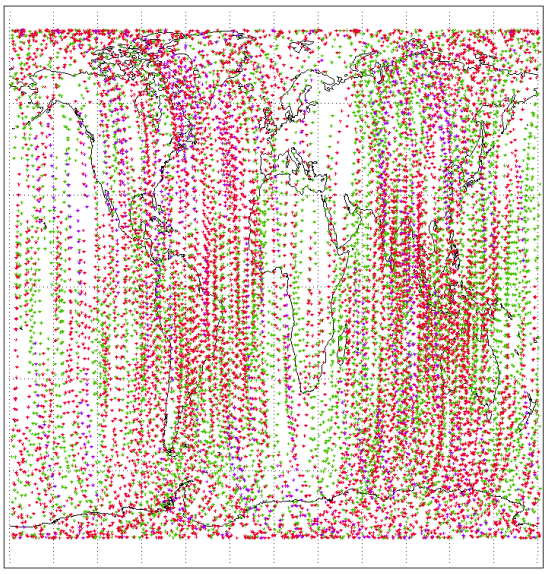
UV background

Tatiana data: web site of the MSU-250 project: *http://cosmos.msu.ru*

Measurements from January 2005 to March 2007
UV range: 300-400 nm
Acceptance cone of UV detector 14° - diameter of the observed area in the atmosphere 250 km
D3 data - see article: UV radiation from the atmosphere: Results of the MSU "Tatiana" satellite measurements, G.K. Garipov et al., Astroparticle Physics, Volume 24, Issues 4-5, 2005, Pages 400-408



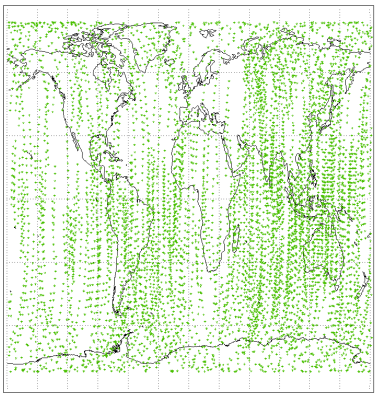
All Tatiana data - positions of measurements



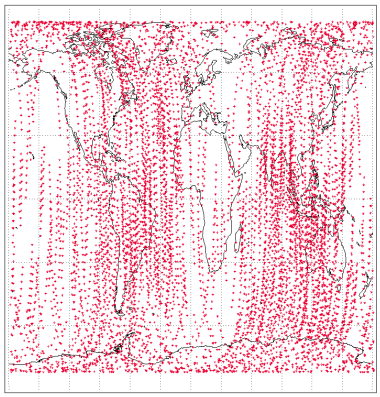
All Tatiana data, green for 2005, red for 2006 and magenta for 2007

Points of measurements year by year

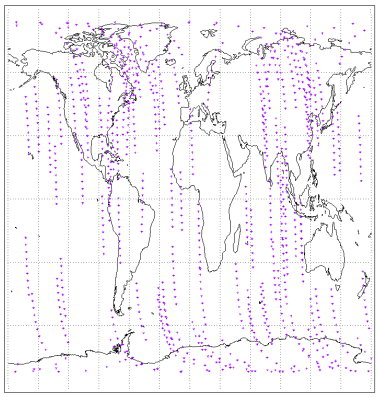
2005



2006



2007



Because JEM-ESUO will measure on the night side, we select from Tatiana data just those where Sun is 18° under local horizon i.e. Sun zenith angle (S_{ZA}) is more than 108°. Alternatively we use for selection S_{ZA} < 112.5° and 90° combined with Moon zenith angle (M_{ZA}) 90°.

Sun zenith angle > 108° , Tatiana trajectory reduced to latitude < 51.6°

- D3 data from region where geo. latitude < 51.6°

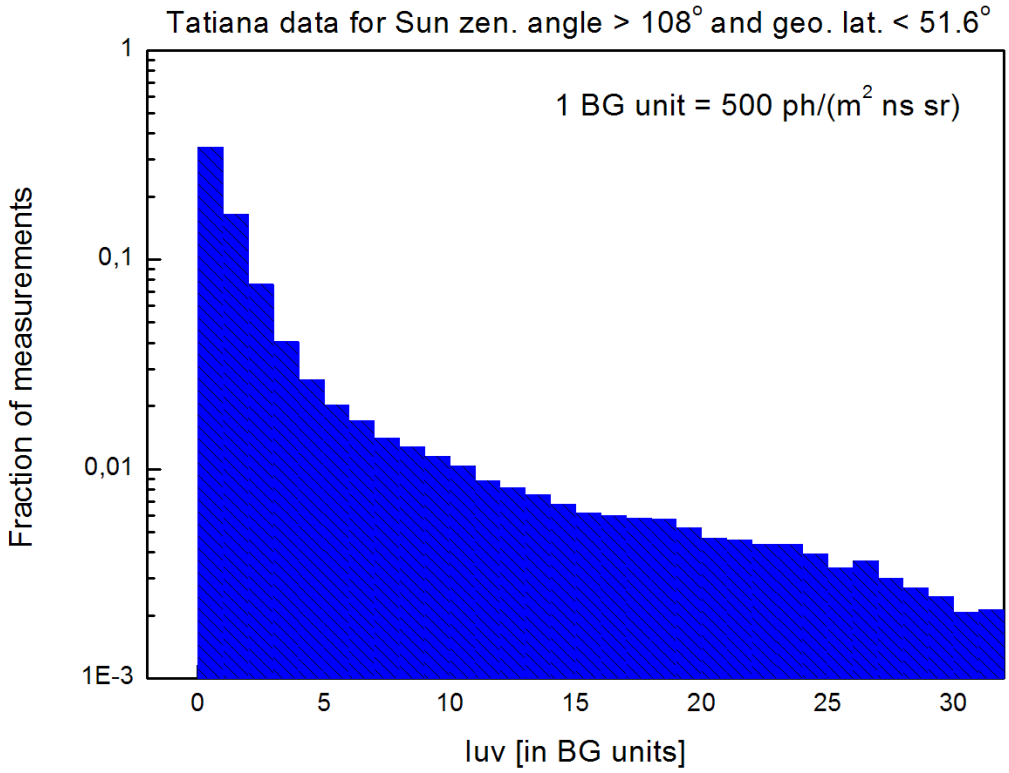


Table 1.

BG in 500 ph/(m^2 s sr)	Coverage [%]	Sum [%]	Rest of hist. [%]
BG x 1	34.4205	34.4205	65.5795
BG x 2	16.5006	50.9211	49.0789
BG x 3	7.6335	58.5546	41.4454
BG x 4	4.0558	62.6104	37.3896
BG x 5	2.6692	65.2797	34.7203
BG x 6	2.0302	67.3099	32.6901
BG x 7	1.7067	69.0166	30.9834
BG x 8	1.3996	70.4161	29.5839
BG x 9	1.2782	71.6943	28.3057
BG x10	1.1520	72.8463	27.1537
BG x11	1.0358	73.8821	26.1179
BG x12	0.8807	74.7629	25.2371
BG x13	0.8142	75.5771	24.4229
BG x14	0.7536	76.3307	23.6693
BG x15	0.6790	77.0097	22.9903
BG x16	0.6153	77.6250	22.3750
BG x17	0.5997	78.2247	21.7753
BG x18	0.5822	78.8069	21.1931
BG x19	0.5760	79.3829	20.6171
BG x20	0.5252	79.9081	20.0919

Average $_{<3xBG}$ = 521.2650 ph/(m^2 s sr)

1. column - UV intensity in BG units, 1 BG = 500 ph/(m^2 s sr)
2. column - fraction of measurements with selected BG level in %
3. column - sum of fractions for BG with UV intensity less than selected BG (= value from 1. column)
4. column - 100% minus value in 3. column

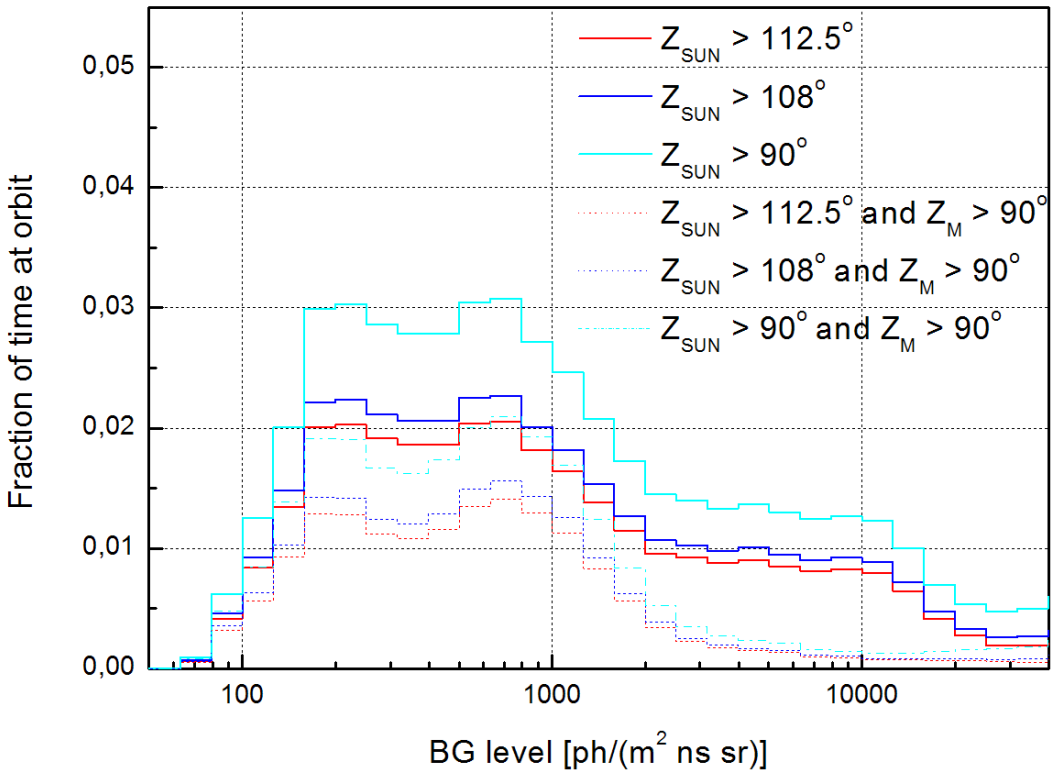


Fig. 1. Fraction of time at orbit (D3 data) for set of S_{ZA} (Z_{SUN} on figure) and Moon zenith angle 90°.

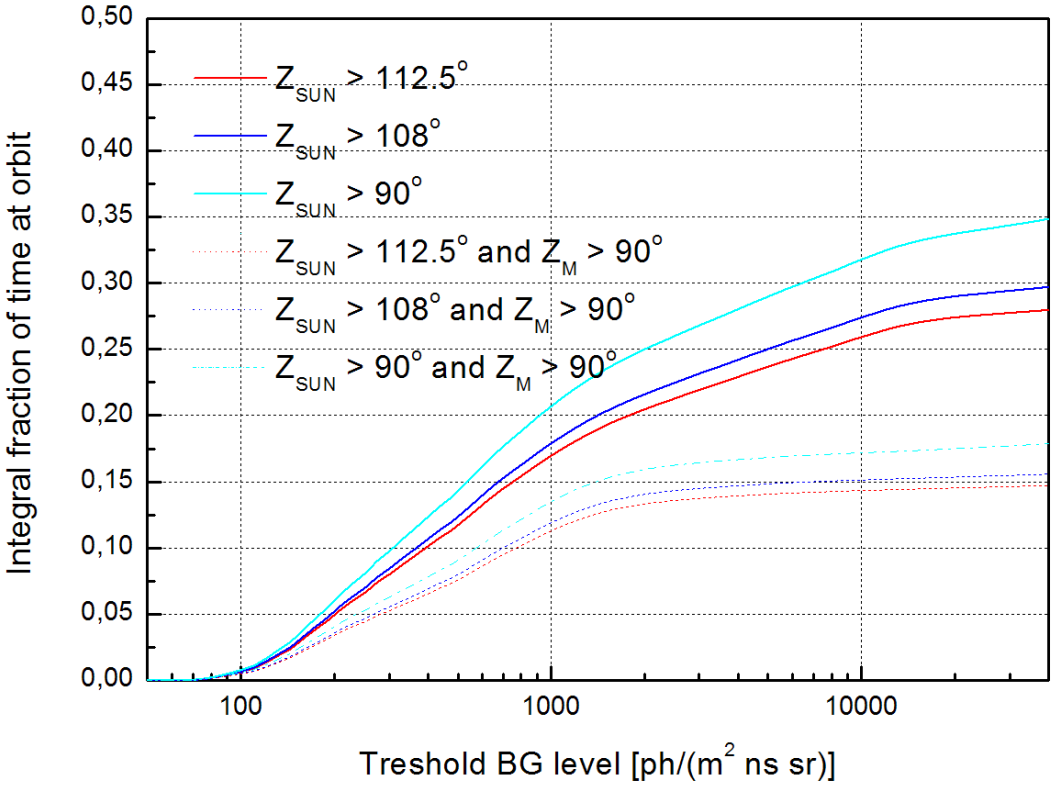


Fig. 2. Integral fraction of time at orbit (D3 data) for set of S_{ZA} (Z_{SUN} on figure) and Moon zenith angle 90° as function of BG treshold.

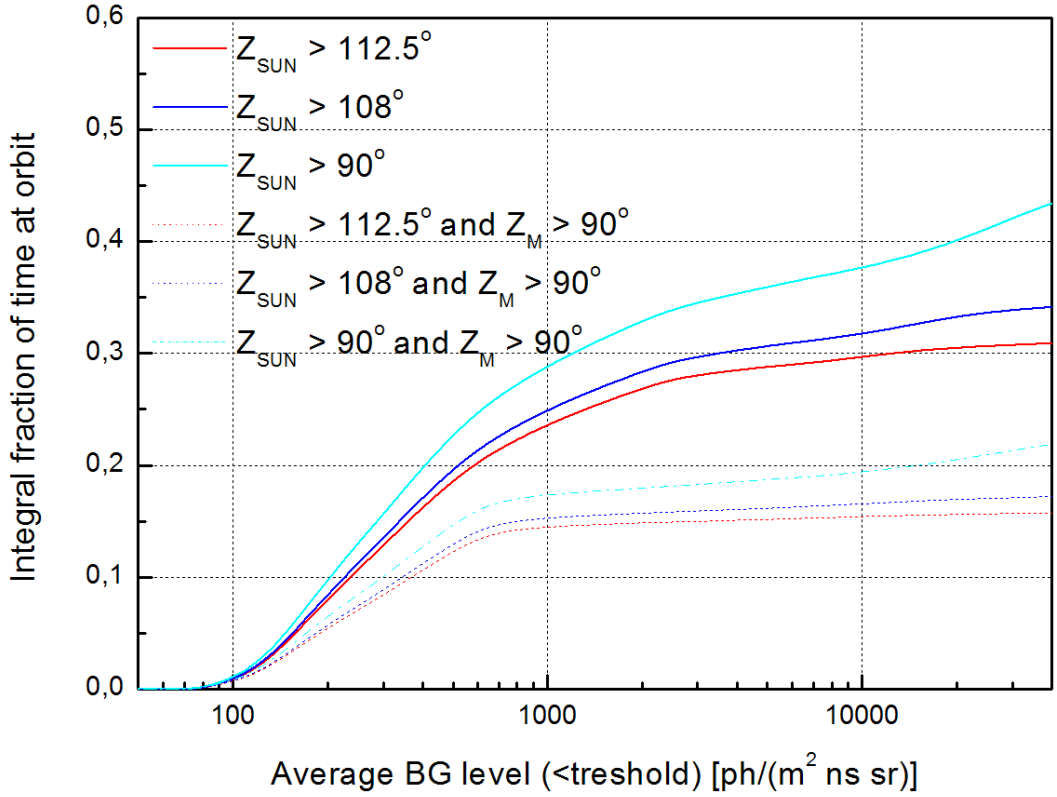


Fig. 3. Integral fraction of time at orbit (D3 data) for set of S_{ZA} (Z_{SUN} on figure) and Moon zenith angle 90o as function average BG level.

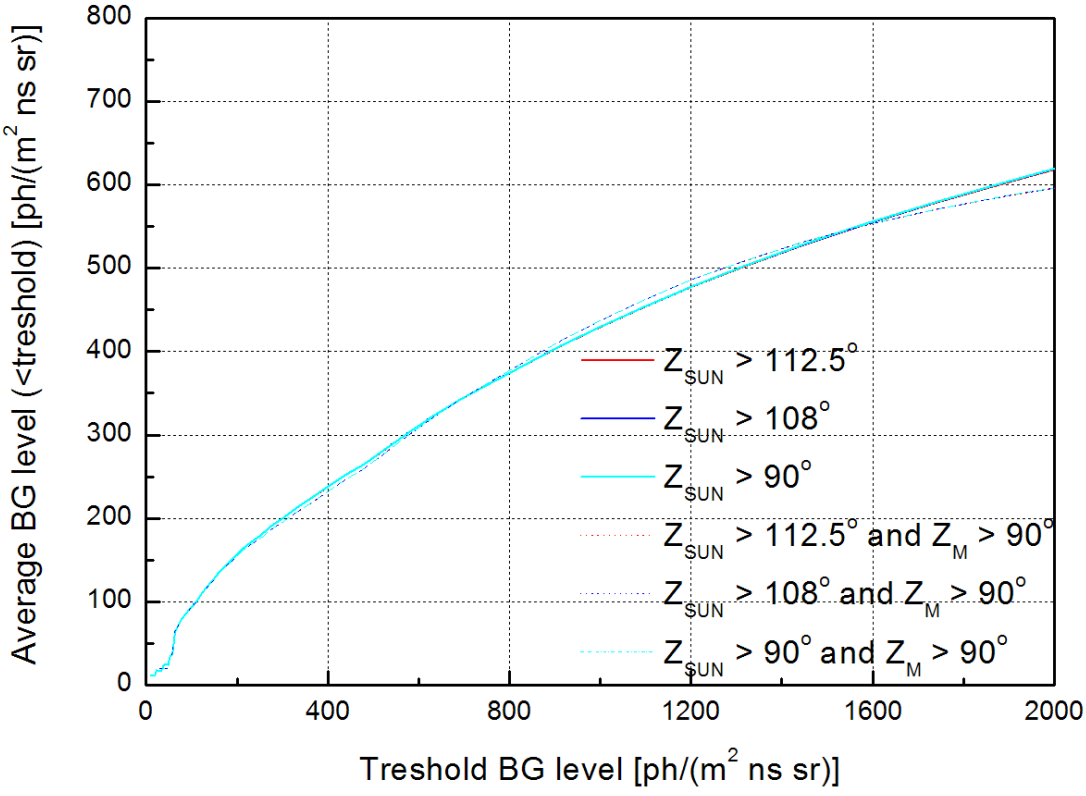


Fig. 4. Average BG level (D3 data) for set of S_{ZA} (Z_{SUN} on figure) and Moon zenith angle 90° as function of treshold BG level.

Trend in data

Hypothesis:
1. BG/duty cycle is time dependent.
2. With 11/22 year periodicity?

We take 6 month and 1 year periods and evaluate duty cycle and average background UV intensity for threshold 1500 ph/(m^2 ns sr) :
6 months periods i.e. (2005.0 - 2005.5), (2005.1 - 2005.6), (2005.2 - 2005.7) etc.
1 year periods i.e. (2005.0 - 2006.0), (2005.1 - 2006.1), (2005.2 - 2006.2) etc.

Results are presented at Fig. 5 (for D3 data).

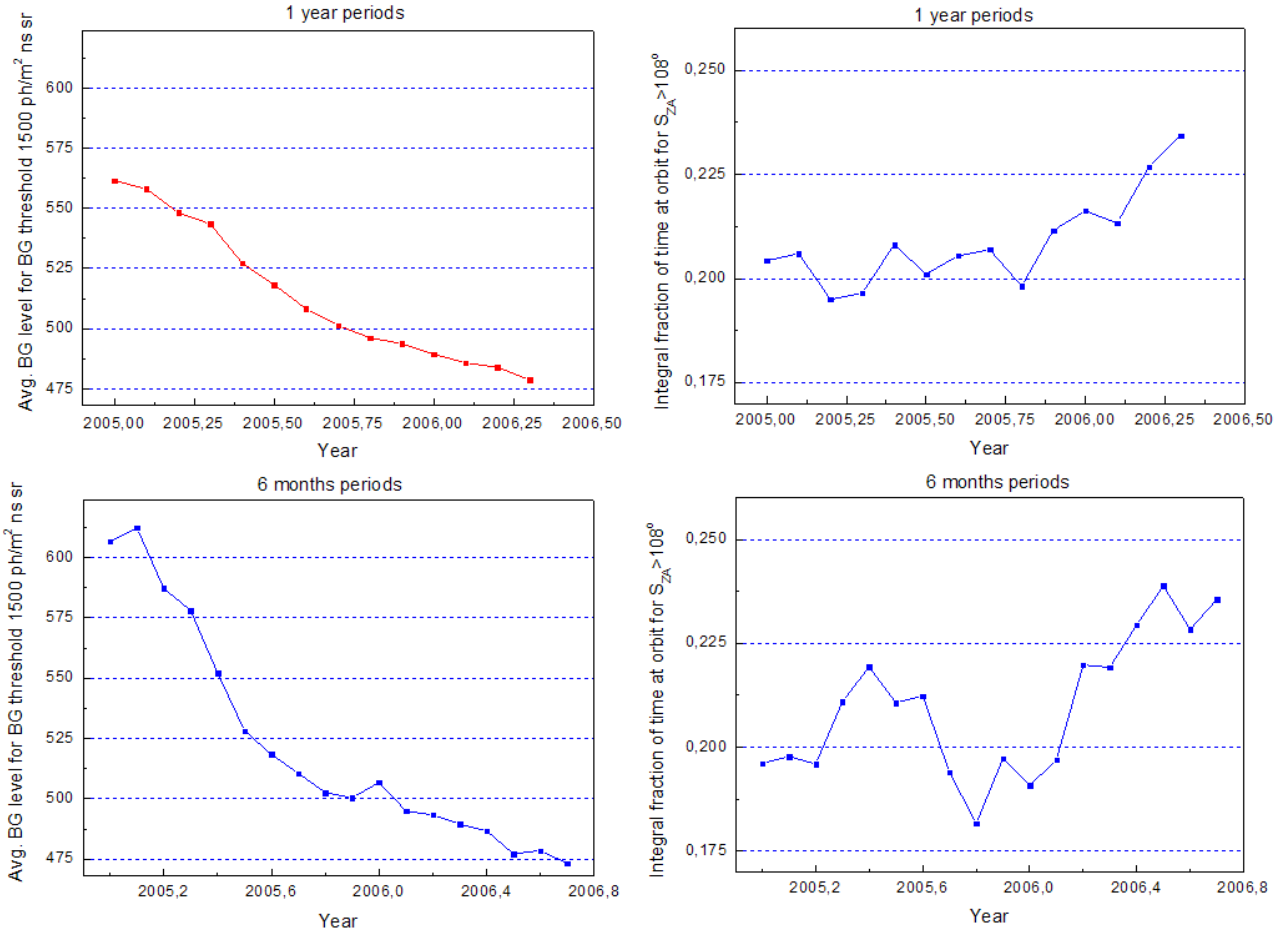


Fig. 5. Average background UV intensities and duty cycle evolution for treshold 1500 ph/(m^2 ns sr). D3 data, S_{ZA} > 108°, lat.<51.6°

I another words we evaluating average BG intensity of UV light for all measurements with intensity below treshold 1500 ph/(m^2 ns sr) in selected periods. Decreasing of avg. intensities with time from 2005 till almost end the year 2006 is consistent with decreasing Sun activity (coming solar minimum in 2008 and 2009).

As is presented on Fig. 6. moon light has no change to this decreasing trend.

Situation for different tresholds is presented on Fig. 7. Threshold are in BG unit (1 BG unit = 500 ph/(m^2 ns sr)). We can see that for lower tresholds we have decreasing trend while higher tresholds show oposite trend. More clear it can be seen from Table 2. where we compare average UV light intensities in first and last of checked half year periods (i.e. periods (2005.0 - 2005.5) and (2006.7 - 2007.2)) for different BG tresholds.

As authors of data explain trend in data appear in connection with increasing difficulties in keeping detector in nadir direction.

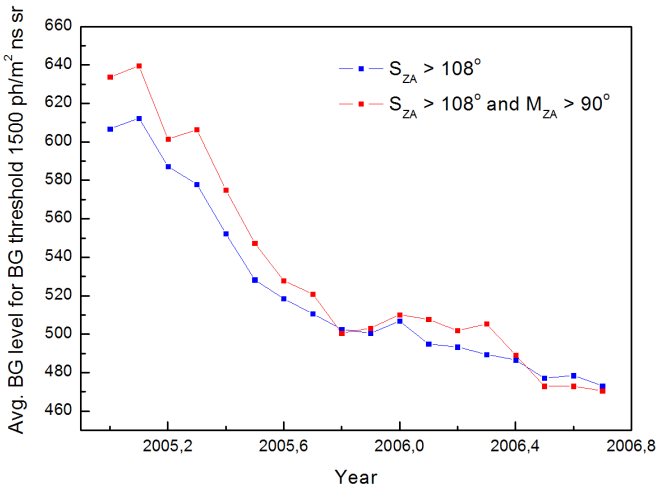


Fig 6. Moon influence to average background UV intensities for treshold 1500 ph/(m^2 ns sr). D3 data, S_{ZA} > 108°, lat.<51.6° (blue) and S_{ZA} > 108°, M_{ZA} >90°, lat.<51.6° (red)

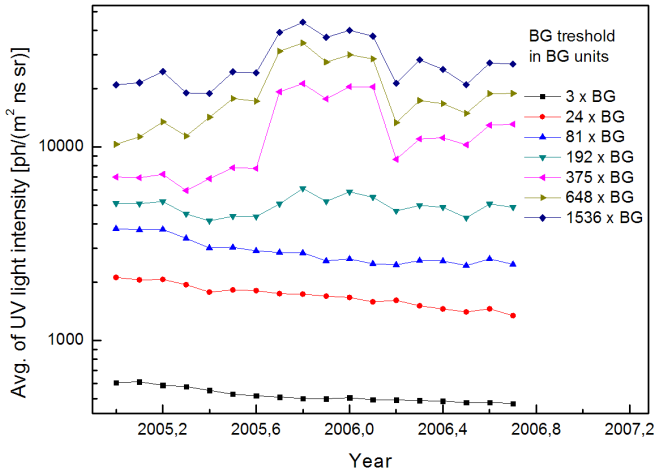
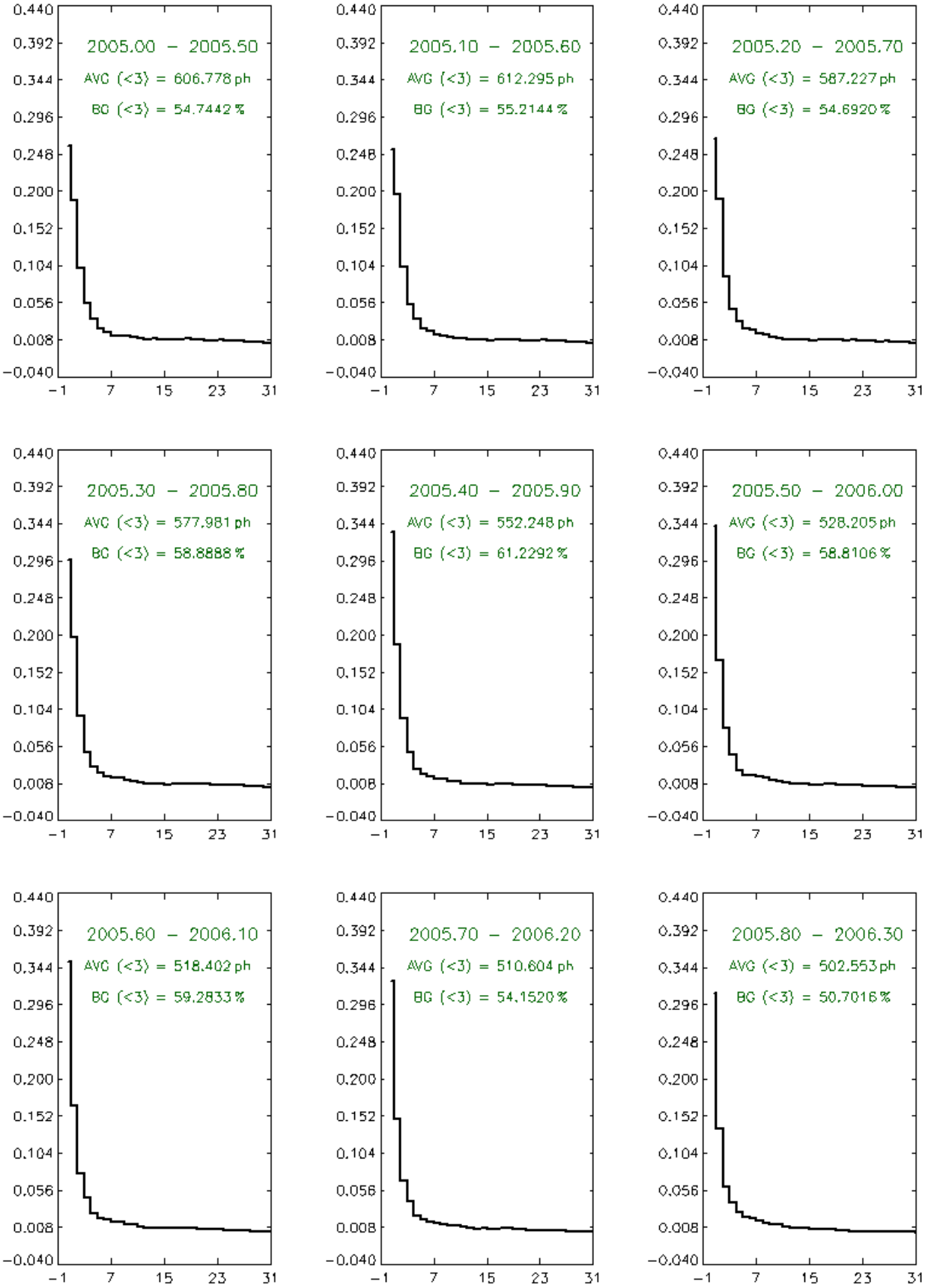


Fig. 7. Average background UV intensities for set of different tresholds.

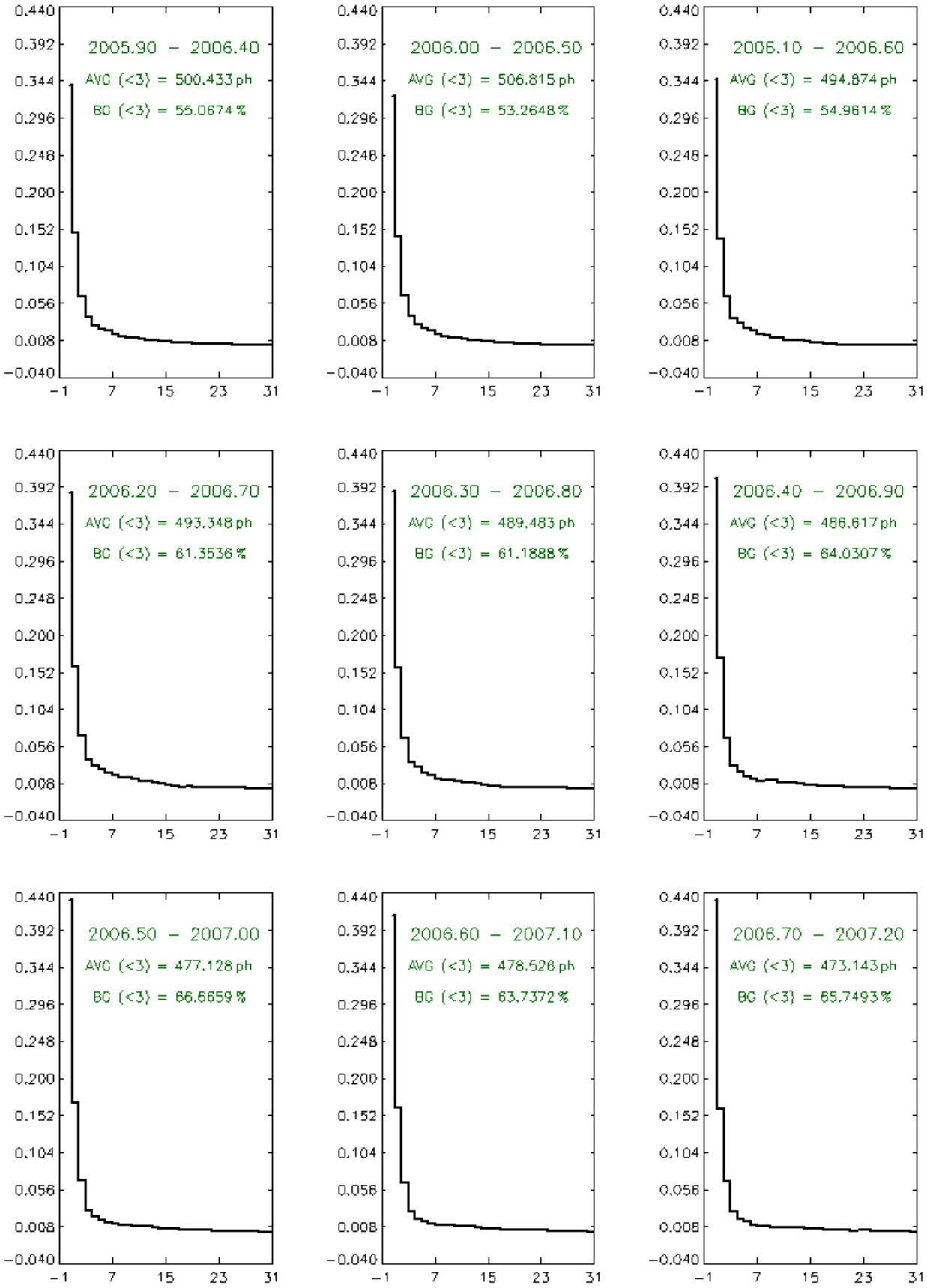
Table 2.

Treshold in BG units [1 BG = 500 ph/(m^2 ns sr)]	Ratio I_{UV} (2005.0) / I_{UV} (2006.7)
BG x 3	1.28
BG x 24	1.58
BG x 81	1.53
BG x 192	1.05
BG x 375	0.53
BG x 648	0.55
BG x 1029	0.78
BG x 1536	0.78
BG x 2187	0.80

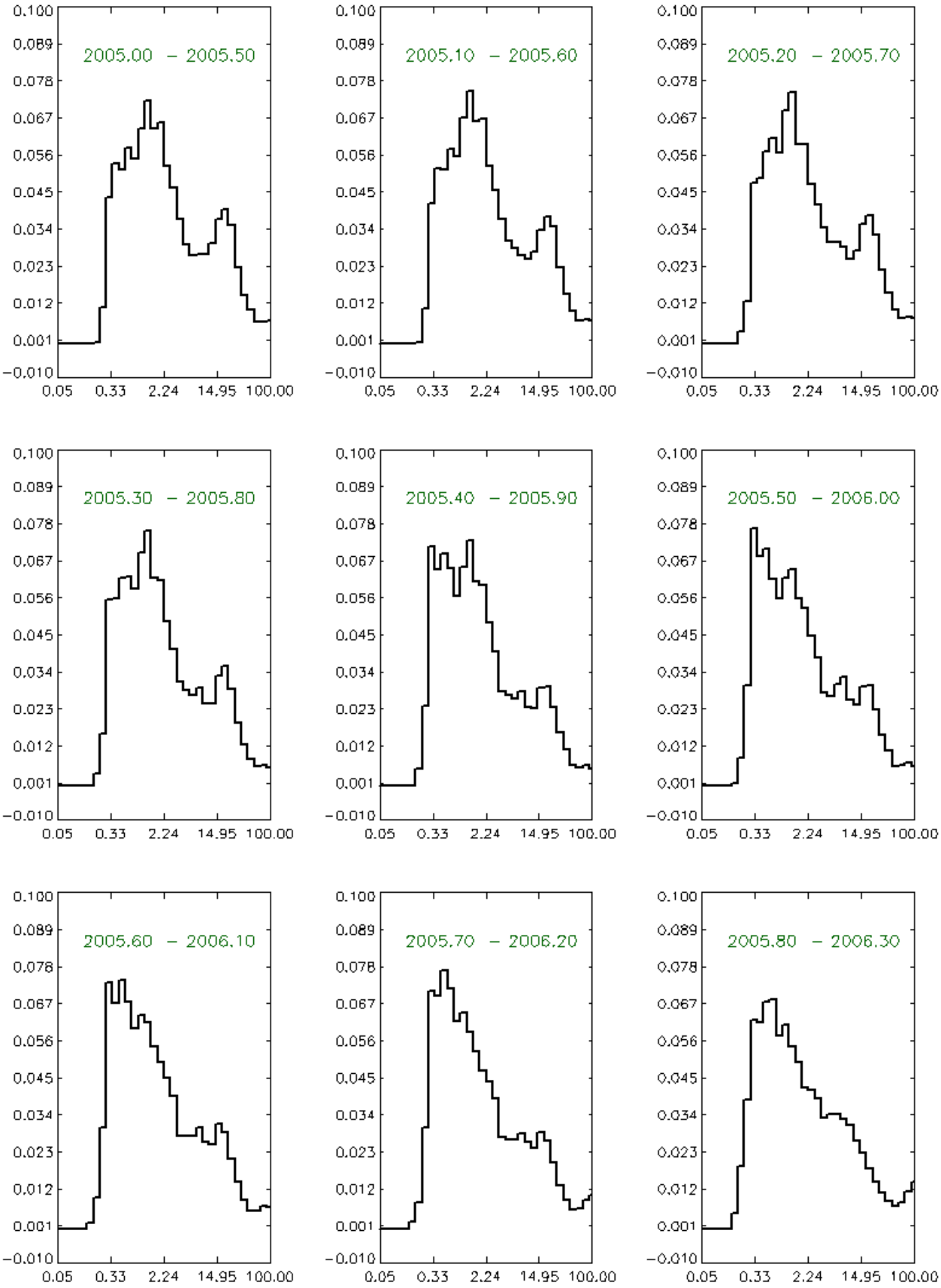
Figures on the next 6 pages show evolution of fraction of time on orbit during night (when S_{ZA} > 108°) histograms during Tatiana measurements.



Fraction of time at orbit for $S_{ZA} > 108^{o}$
D3 data, $S_{ZA} > 108^{o}$, lat.<51.6°, in BG units [1 BG = 500 ph/(m^2 ns sr)]

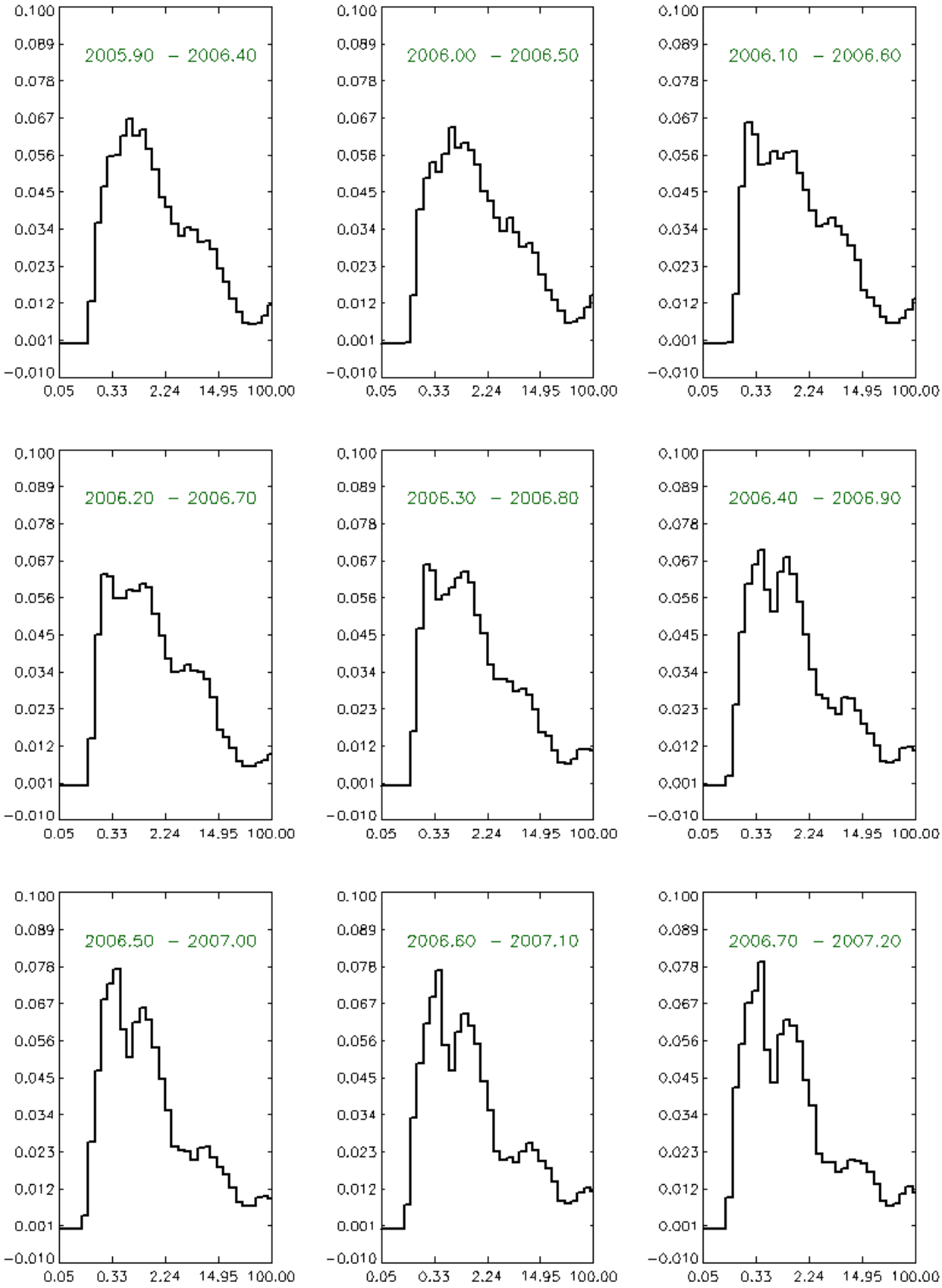


Fraction of time at orbit for $S_{ZA} > 108°$
D3 data, $S_{ZA} > 108°$, lat.<51.6°, in BG units [1 BG = 500 ph/(m^2 ns sr)]

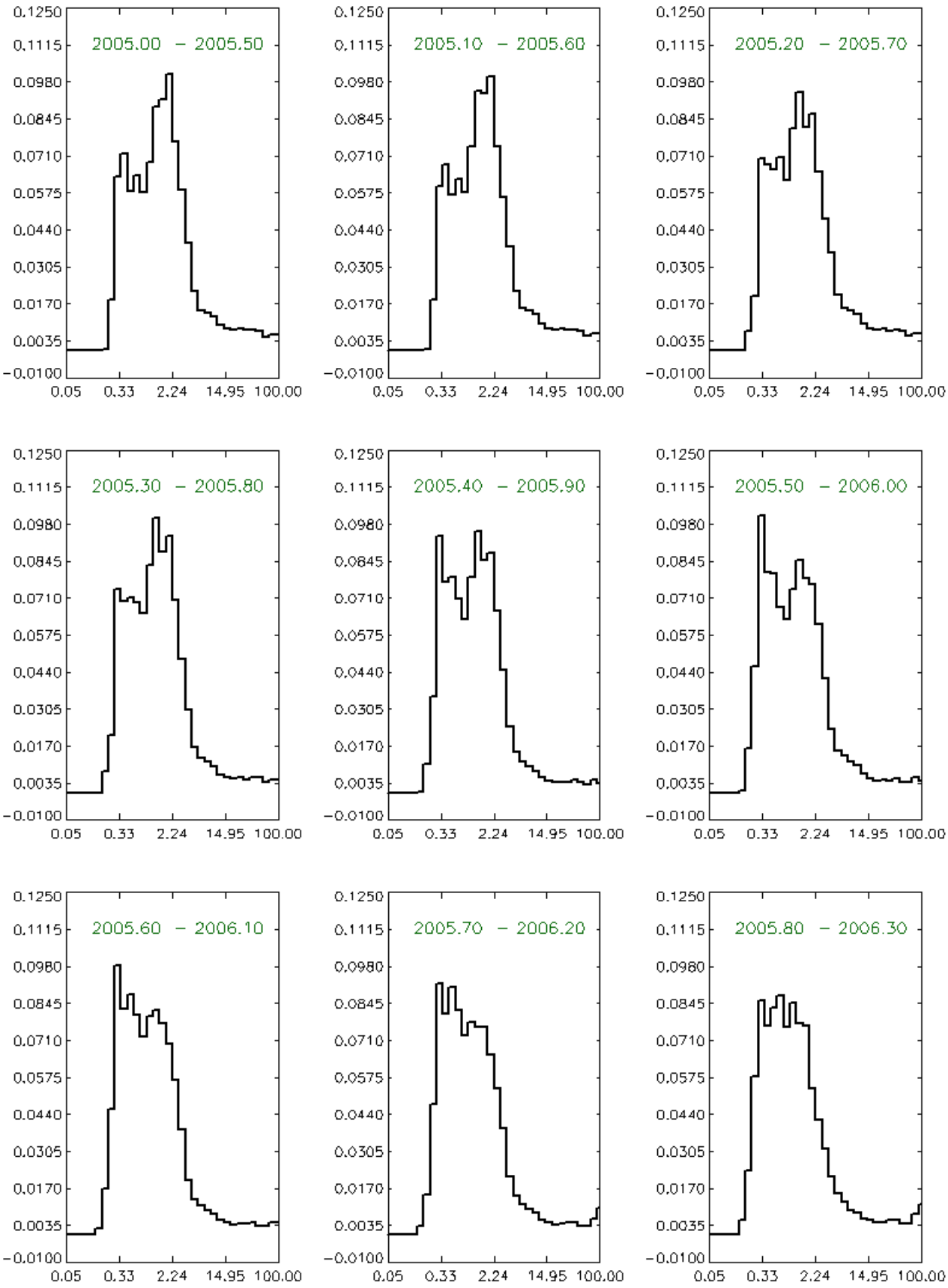


Fraction of time at orbit for $S_{ZA} > 108^{\circ}$

D3 data, $S_{ZA} > 108^{\circ}$, lat.<51.6°, in BG units [1 BG = 500 ph/(m^2 ns sr)]

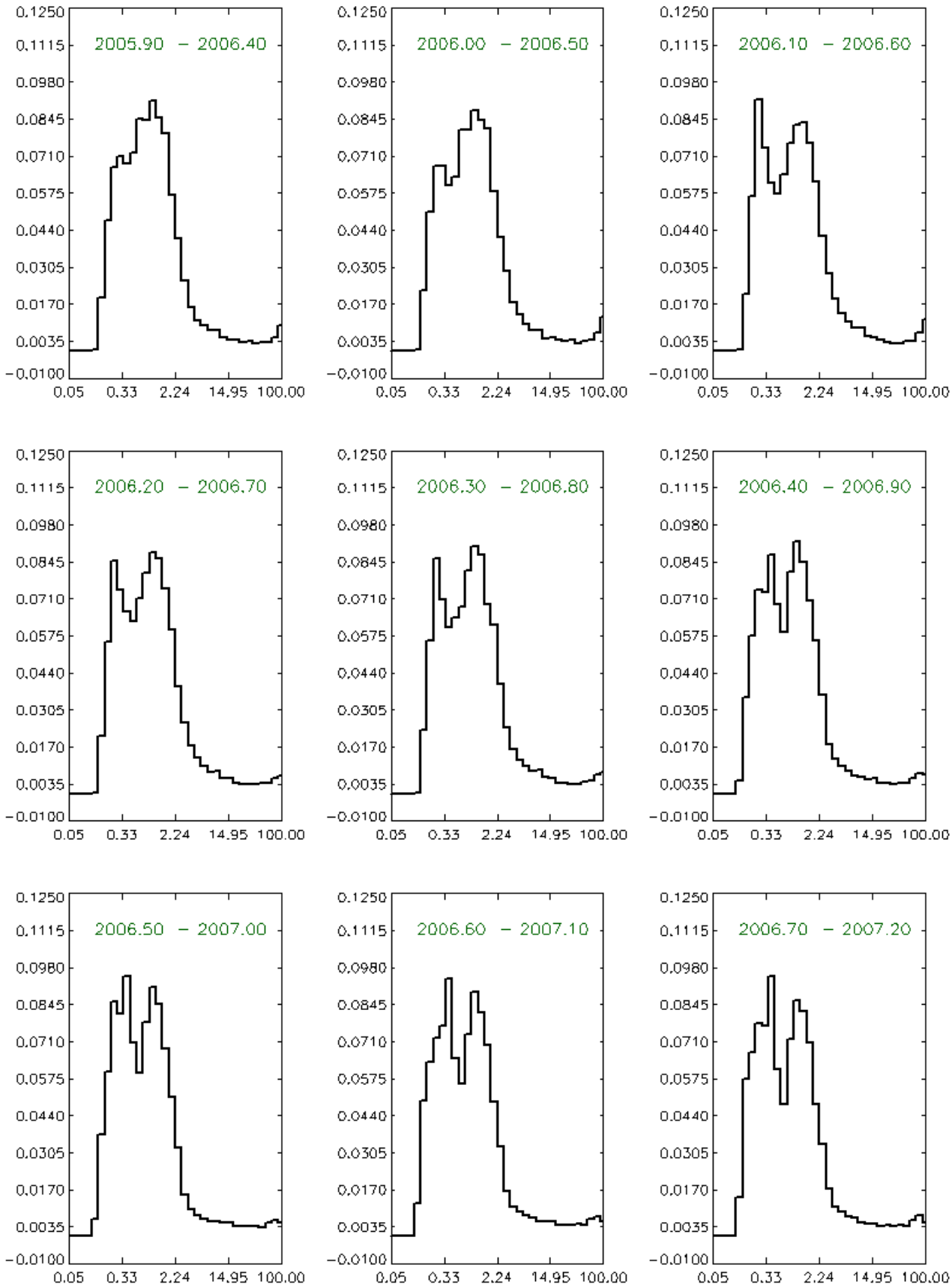


Fraction of time at orbit for $S_{ZA} > 108°$
D3 data, $S_{ZA} > 108°$, lat.< 51.6°, in BG units [1 BG = 500 ph/(m^2 ns sr)]



Fraction of time at orbit for S_{ZA} > 108°, Mza>90°

D3 data, S_{ZA} > 108°, M_{ZA}>90°, lat.<51.6°, in BG units [1 BG = 500 ph/(m^2 ns sr)]



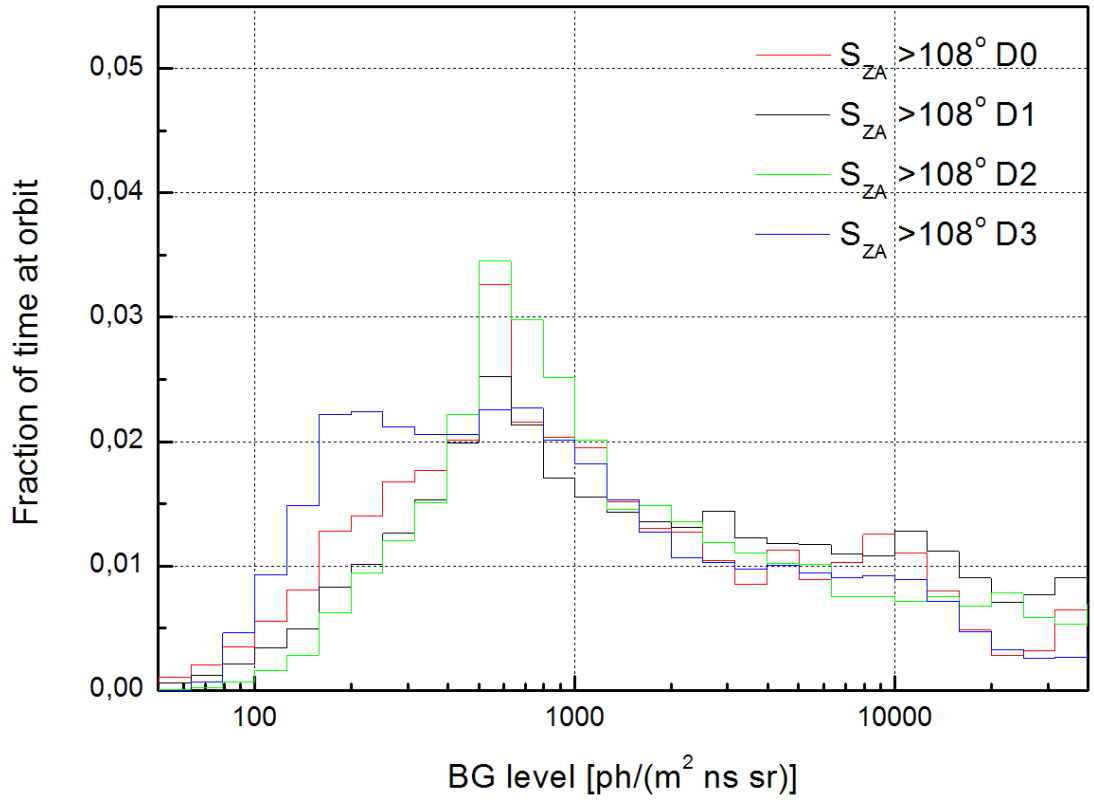
Fraction of time at orbit for S_{ZA} > 108°, M_{ZA}>90°

D3 data, S_{ZA} > 108°, M_{ZA}>90°, lat.<51.6°, in BG units [1 BG = 500 ph/(m^2 ns sr)]

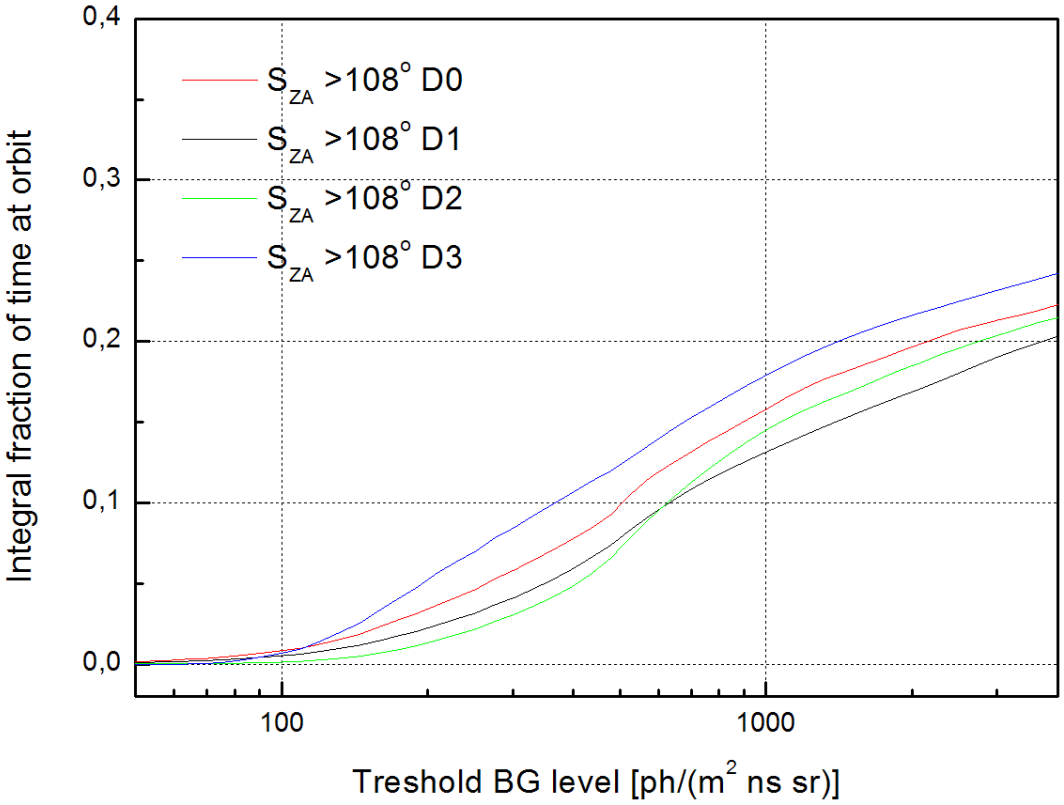
Comparisson of D0, D1, D2 and D3 data

Tatiana measurements are in form so called D0, D1, D2, and D3 data. D3 data are most appropriate for BG / duty cycle estimation (see data and article: Astroparticle Physics, Volume 24, Issues 4-5, 2005, Pages 400-408, UV radiation from the atmosphere: Results of the MSU "Tatiana" satellite measurements, G.K. Garipov, et al.).

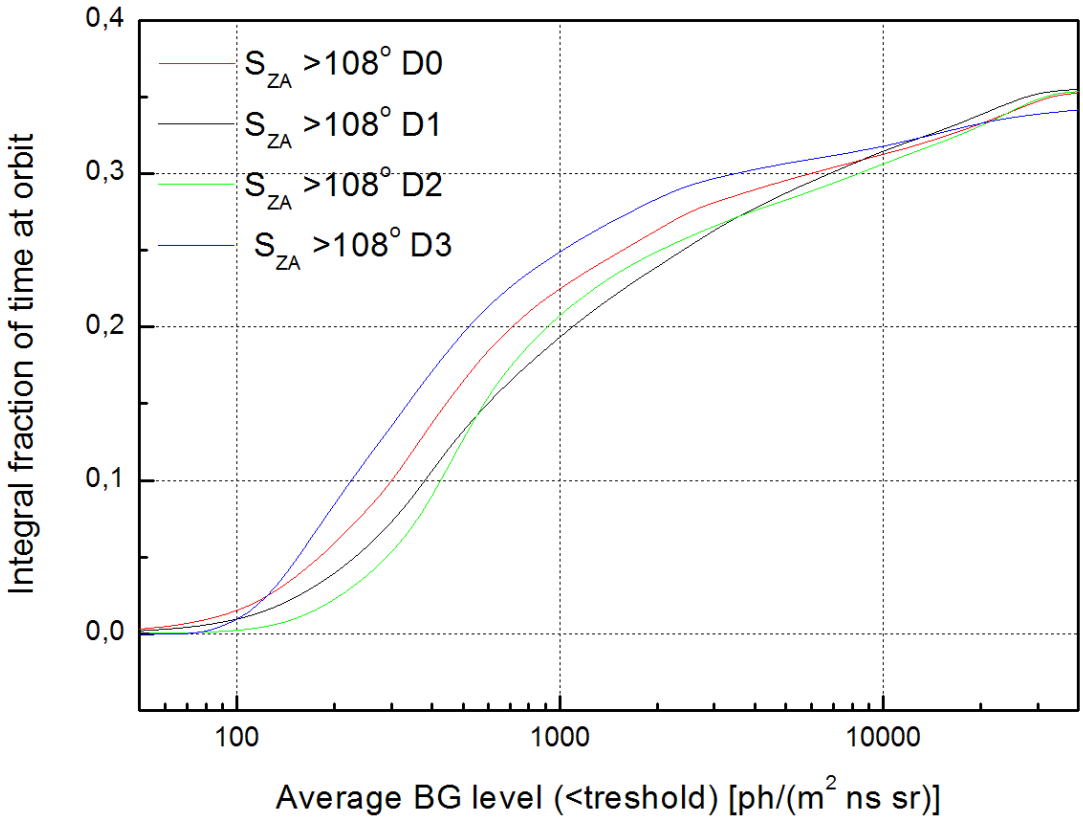
D0 - time sample 1 mcs
D1 - time sample 16 mcs
D2 - time sample 256 mcs
D3 - time sample 4 s



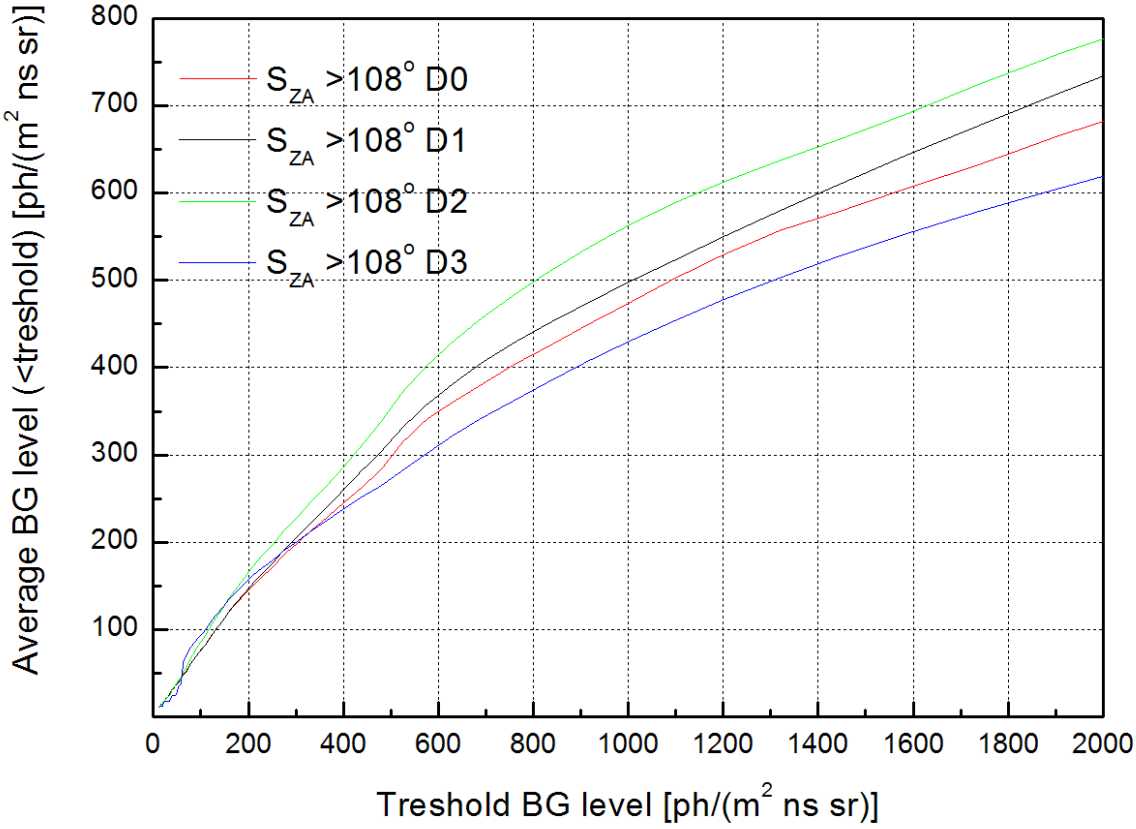
Histograms of fraction of time at orbit for D0,D1,D2 and D3 data.
Data for S_{ZA} > 108° and latitude > 51.6°.



Integral fraction of time (IFoT) at orbit for D0,D1,D2 and D3 data.
Data for S_{ZA} > 108° and latitude > 51.6°.



IFoT for D0,D1,D2 and D3 data. Data for S_{ZA} > 108° and latitude > 51.6°.



Averagge BG level for D0,D1,D2 and D3 data.
Data for Sza > 108° and latitude > 51.6°.

D1 data

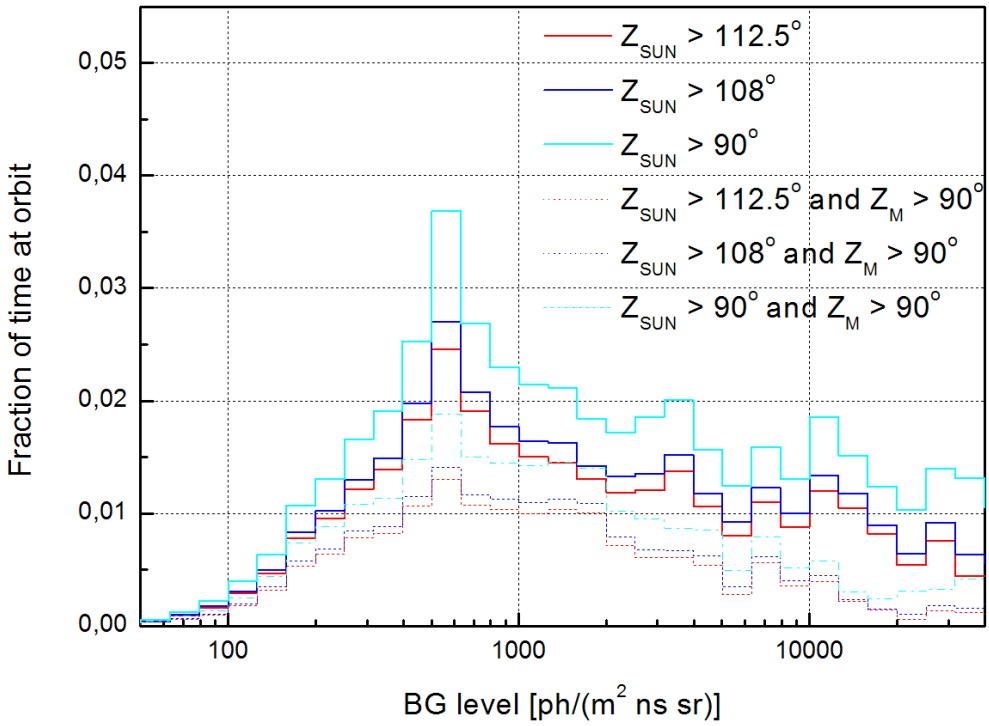


Fig. Fraction of time at orbit (D1 data) for set of S_{ZA} (Z_{SUN} on figure) and Moon zenith angle 90°.

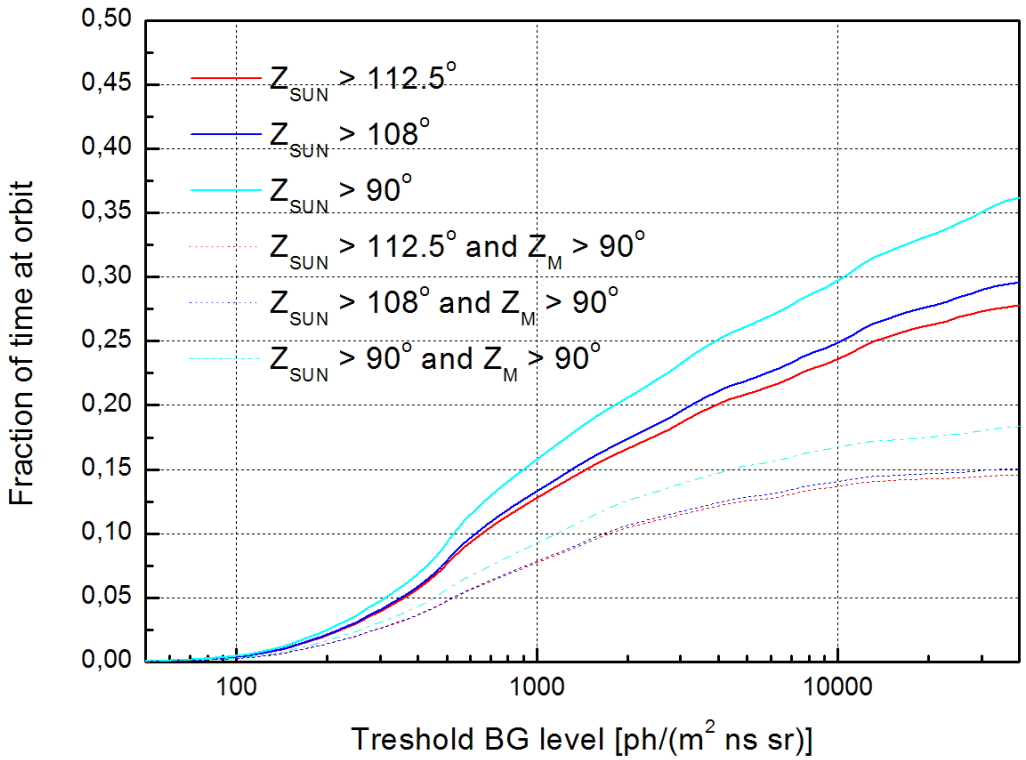


Fig. Integral fraction of time at orbit (D1 data) for set of S_{ZA} (Z_{SUN} on figure) and Moon zenith angle 90° as function of BG treshold.

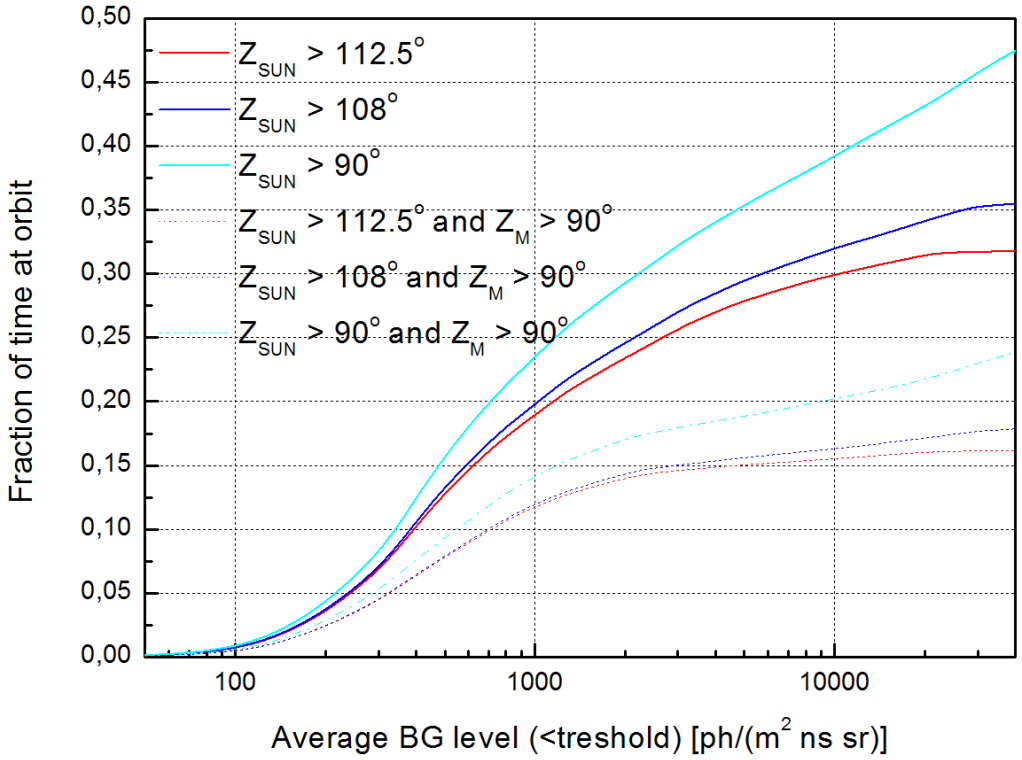


Fig. 3. Integral fraction of time at orbit (D1 data) for set of S_{ZA} (Z_{SUN} on figure) and Moon zenith angle 90o as function average BG level.

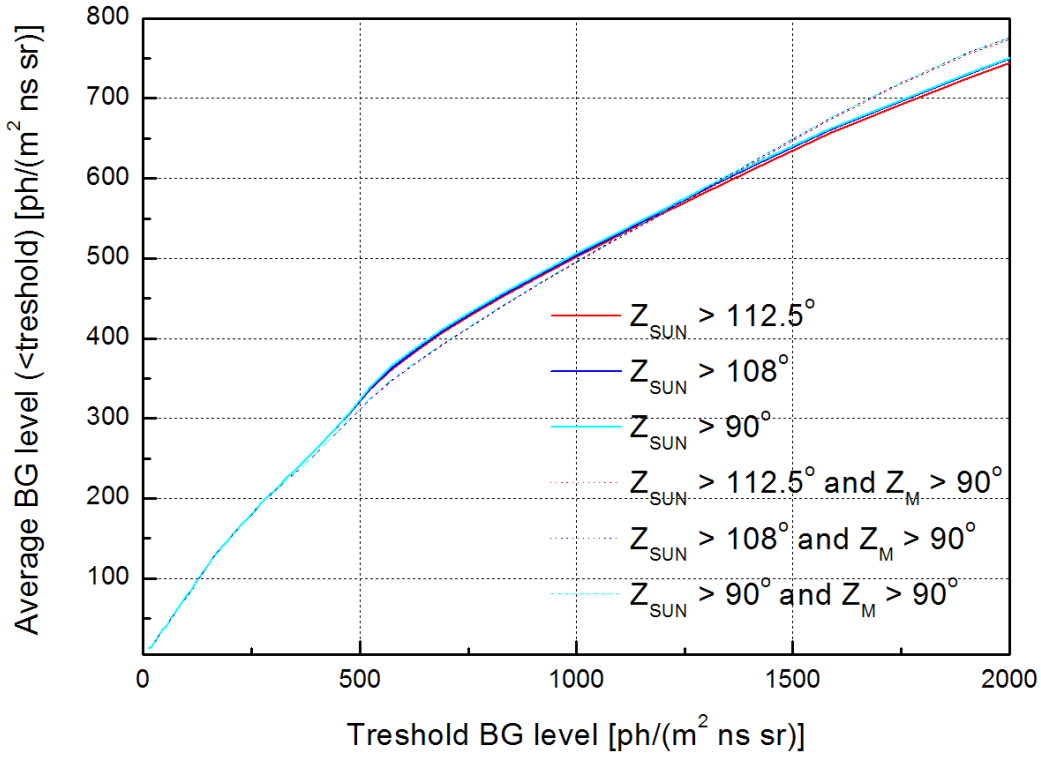


Fig. Average BG level (D1 data) for set of S_{ZA} (Z_{SUN} on figure) and Moon zenith angle 90° as function of treshold BG level.

Sun zenith angle > 108° , Tatiana trajectory reduced to latitude < 51.6°

- D1 data from region where geo. latitude < 51.6°

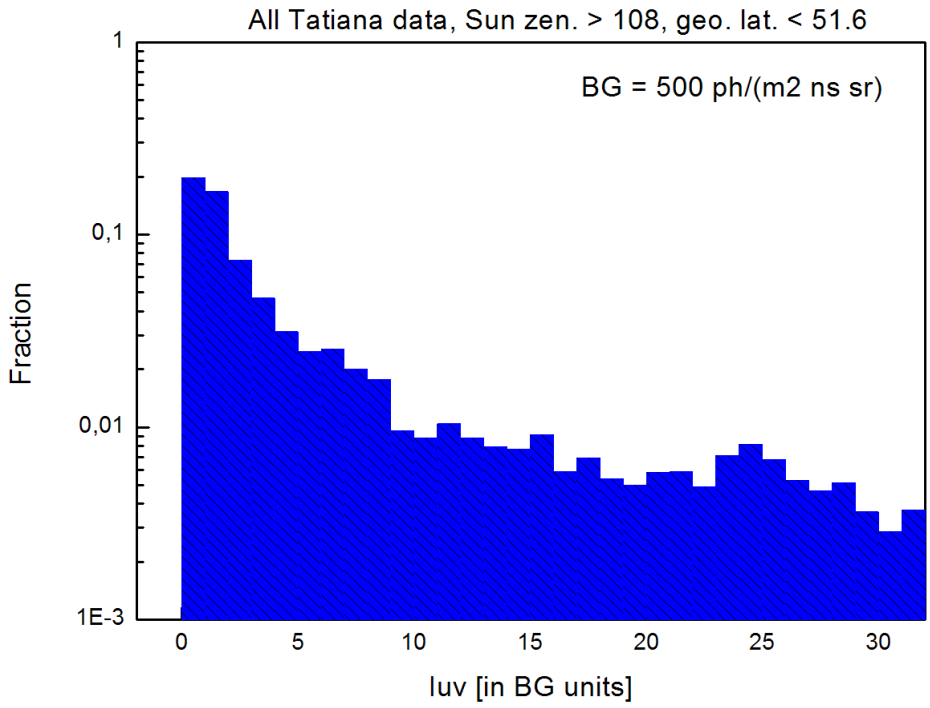


Table 1.

BG in 500 ph/(m^2 s sr)	Coverage [%]	Sum [%]	Rest of hist. [%]
BG x 1	19.8193	19.8193	80.1807
BG x 2	16.7112	36.5305	63.4695
BG x 3	7.3583	43.8888	56.1112
BG x 4	4.6808	48.5696	51.4304
BG x 5	3.1333	51.7028	48.2972
BG x 6	2.4640	54.1669	45.8331
BG x 7	2.5436	56.7104	43.2896
BG x 8	1.9962	58.7066	41.2934
BG x 9	1.7660	60.4727	39.5273
BG x10	0.9603	61.4330	38.5670
BG x11	0.8803	62.3132	37.6868
BG x12	1.0419	63.3551	36.6449
BG x13	0.8747	64.2299	35.7701
BG x14	0.7926	65.0225	34.9775
BG x15	0.7669	65.7894	34.2106
BG x16	0.9160	66.7054	33.2946
BG x17	0.5852	67.2906	32.7094
BG x18	0.6934	67.9840	32.0160
BG x19	0.5398	68.5239	31.4761
BG x20	0.5001	69.0239	30.9761

Average $_{<3xBG}$ = 608.04 ph/(m^2 s sr)

1. column - UV intensity in BG units, 1 BG = 500 ph/(m^2 s sr)
2. column - fraction of measurements with selected BG level in %
3. column - sum of fractions for BG with UV intensity less than selected BG (= value from 1. column)
4. column - 100% - value in 3. column

Sun zenith angle > 108° - ISS trajectory (Tatiana measurements normalized-weighted to latitudinal position distribution of ISS orbit), D1 data

Probability to find a Tatiana and ISS on same latitude is different due to their different orbits. Normalization of Tatiana measurements to ISS latitudinal distribution is presented on next histogram.

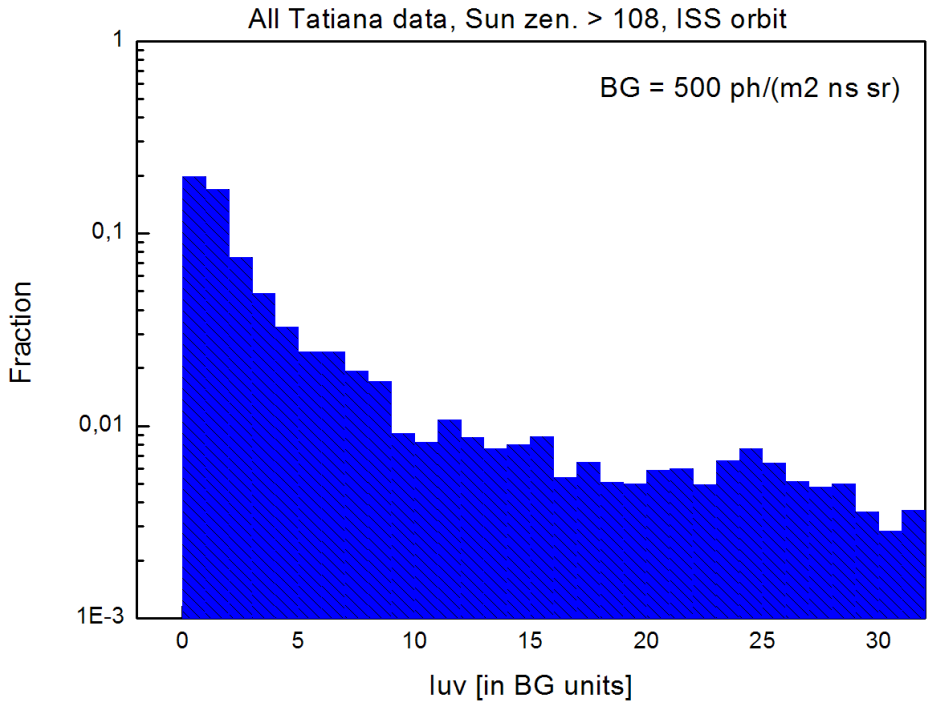


Table 2.

BG in 500 ph/(m^2 s sr)	Coverage [%]	Sum [%]	Rest of hist. [%]
BG x 1	19.7484	19.7484	80.2516
BG x 2	16.9522	36.7006	63.2994
BG x 3	7.4995	44.2001	55.7999
BG x 4	4.8590	49.0591	50.9409
BG x 5	3.2555	52.3146	47.6854
BG x 6	2.4247	54.7393	45.2607
BG x 7	2.4292	57.1684	42.8316
BG x 8	1.9341	59.1025	40.8975
BG x 9	1.6990	60.8015	39.1985
BG x10	0.9122	61.7137	38.2863
BG x11	0.8228	62.5364	37.4636
BG x12	1.0755	63.6119	36.3881
BG x13	0.8729	64.4848	35.5152
BG x14	0.7600	65.2448	34.7552
BG x15	0.8001	66.0449	33.9551
BG x16	0.8801	66.9249	33.0751
BG x17	0.5374	67.4624	32.5376
BG x18	0.6459	68.1082	31.8918
BG x19	0.5095	68.6178	31.3822
BG x20	0.4985	69.1163	30.8837

Number of Tatiana measurements: 195 790

Sun zenith angle > 90° (Tatiana measurements normalized-weighted to latitudinal position distribution of ISS orbit), D1 data

- to check a dependency on UV light intensity at Sun zenith angle we made a selection for different Sun zenith angles i.e. 90°, 90.5° and 91°.

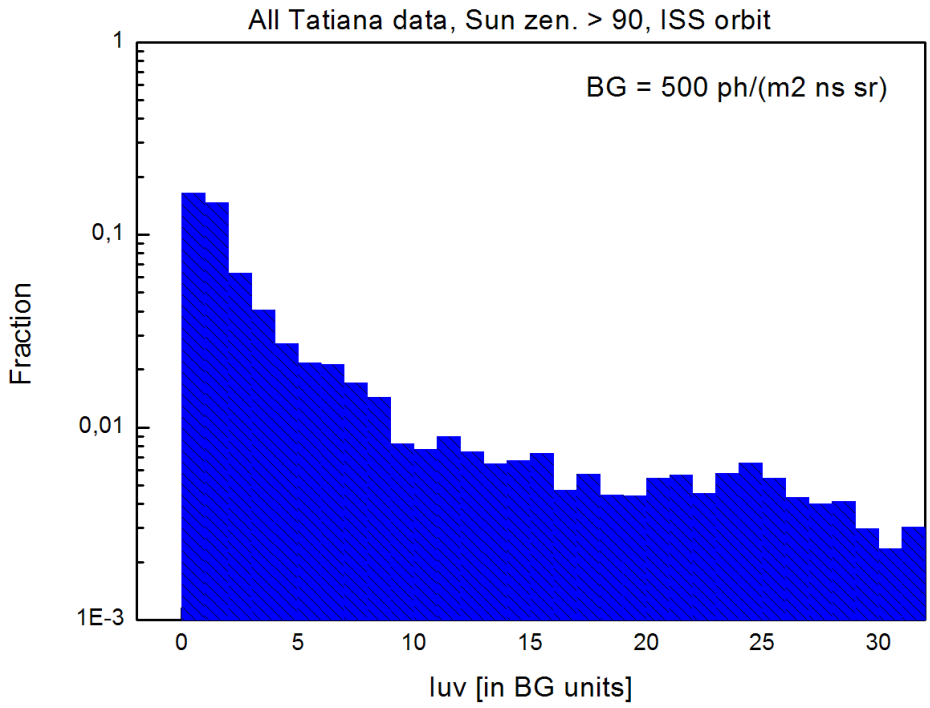


Table 3.

BG in 500 ph/(m^2 s sr)	Coverage [%]	Sum [%]	Rest of hist. [%]
BG x 1	16.3989	16.3989	83.6011
BG x 2	14.6685	31.0673	68.9327
BG x 3	6.3045	37.3718	62.6282
BG x 4	4.0715	41.4434	58.5566
BG x 5	2.7186	44.1619	55.8381
BG x 6	2.1554	46.3173	53.6827
BG x 7	2.1187	48.4360	51.5640
BG x 8	1.7040	50.1400	49.8600
BG x 9	1.4353	51.5753	48.4247
BG x10	0.8237	52.3990	47.6010
BG x11	0.7693	53.1683	46.8317
BG x12	0.8953	54.0637	45.9363
BG x13	0.7448	54.8084	45.1916
BG x14	0.6474	55.4558	44.5442
BG x15	0.6715	56.1273	43.8727
BG x16	0.7345	56.8619	43.1381
BG x17	0.4720	57.3338	42.6662
BG x18	0.5719	57.9057	42.0943
BG x19	0.4450	58.3507	41.6493
BG x20	0.4432	58.7939	41.2061

Number of Tatiana measurements: 229 847

Sun zenith angle > 90.5° , ISS trajectory (Tatiana measurements normalized-weighted to latitudinal position distribution of ISS orbit), D1 data

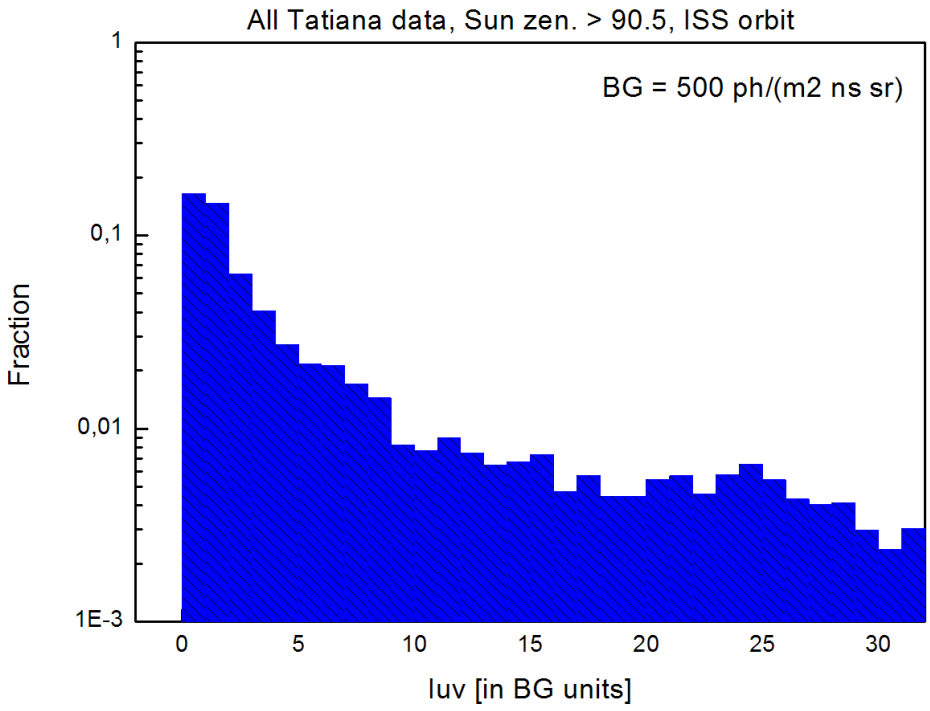


Table 4.

BG in 500 ph/(m^2 s sr)	Coverage [%]	Sum [%]	Rest of hist. [%]
BG x 1	16.4342	16.4342	83.5658
BG x 2	14.7001	31.1343	68.8657
BG x 3	6.3181	37.4524	62.5476
BG x 4	4.0803	41.5327	58.4673
BG x 5	2.7244	44.2571	55.7429
BG x 6	2.1600	46.4172	53.5828
BG x 7	2.1233	48.5404	51.4596
BG x 8	1.7077	50.2481	49.7519
BG x 9	1.4384	51.6865	48.3135
BG x10	0.8255	52.5120	47.4880
BG x11	0.7710	53.2830	46.7170
BG x12	0.8973	54.1802	45.8198
BG x13	0.7464	54.9266	45.0734
BG x14	0.6488	55.5754	44.4246
BG x15	0.6729	56.2483	43.7517
BG x16	0.7361	56.9845	43.0155
BG x17	0.4730	57.4574	42.5426
BG x18	0.5731	58.0306	41.9694
BG x19	0.4460	58.4765	41.5235
BG x20	0.4441	58.9207	41.0793

Number of Tatiana measurements: 229 362

Sun zenith angle > 91° , ISS trajectory (Tatiana measurements normalized-weighted to latitudinal position distribution of ISS orbit), D1 data

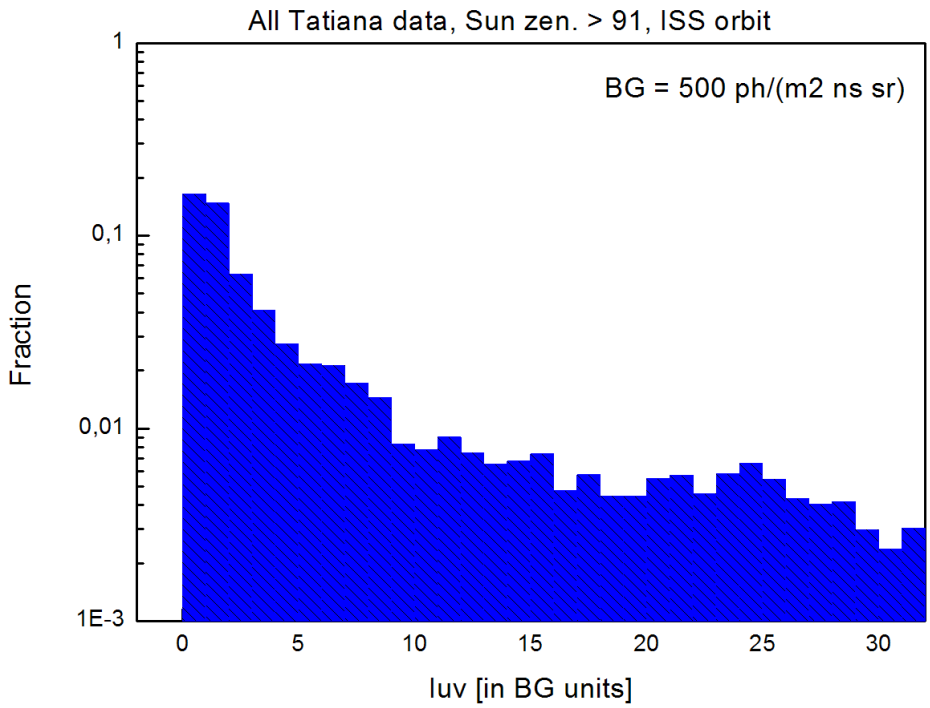
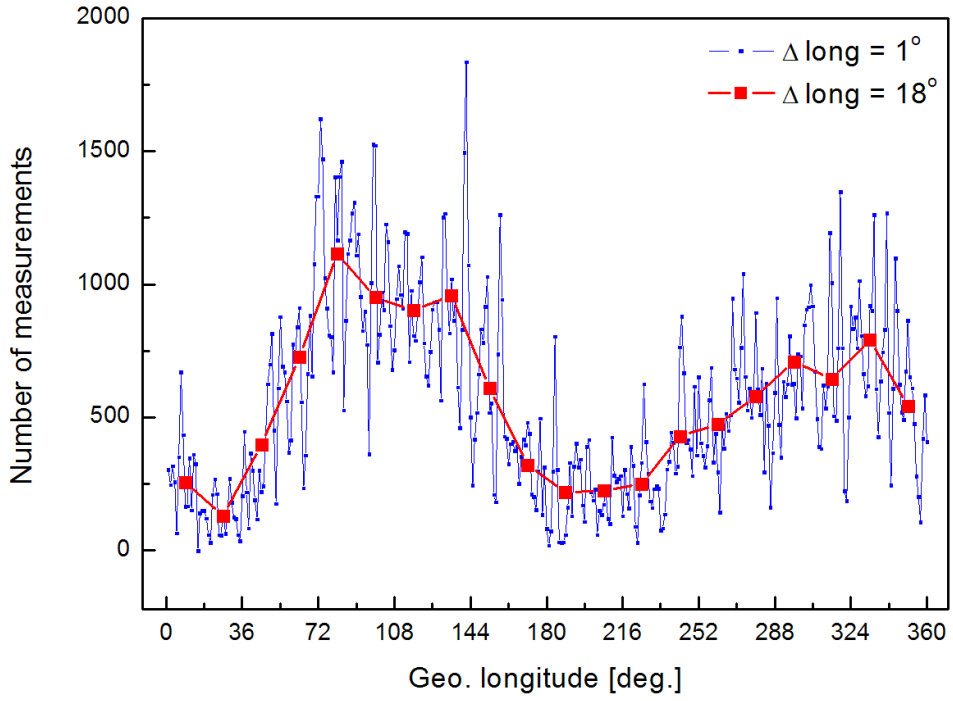


Table 5.

BG in 500 ph/(m^2 s sr)	Coverage [%]	Sum [%]	Rest of hist. [%]
BG x 1	16.4916	16.4916	83.5084
BG x 2	14.7384	31.2300	68.7700
BG x 3	6.3401	37.5701	62.4299
BG x 4	4.0945	41.6646	58.3354
BG x 5	2.7339	44.3986	55.6014
BG x 6	2.1676	46.5661	53.4339
BG x 7	2.1307	48.6968	51.3032
BG x 8	1.7137	50.4105	49.5895
BG x 9	1.4434	51.8539	48.1461
BG x10	0.8284	52.6822	47.3178
BG x11	0.7737	53.4559	46.5441
BG x12	0.9004	54.3563	45.6437
BG x13	0.7490	55.1053	44.8947
BG x14	0.6511	55.7563	44.2437
BG x15	0.6753	56.4316	43.5684
BG x16	0.7387	57.1703	42.8297
BG x17	0.4746	57.6449	42.3551
BG x18	0.5751	58.2201	41.7799
BG x19	0.4475	58.6676	41.3324
BG x20	0.4457	59.1133	40.8867

Number of Tatiana measurements: 228 691

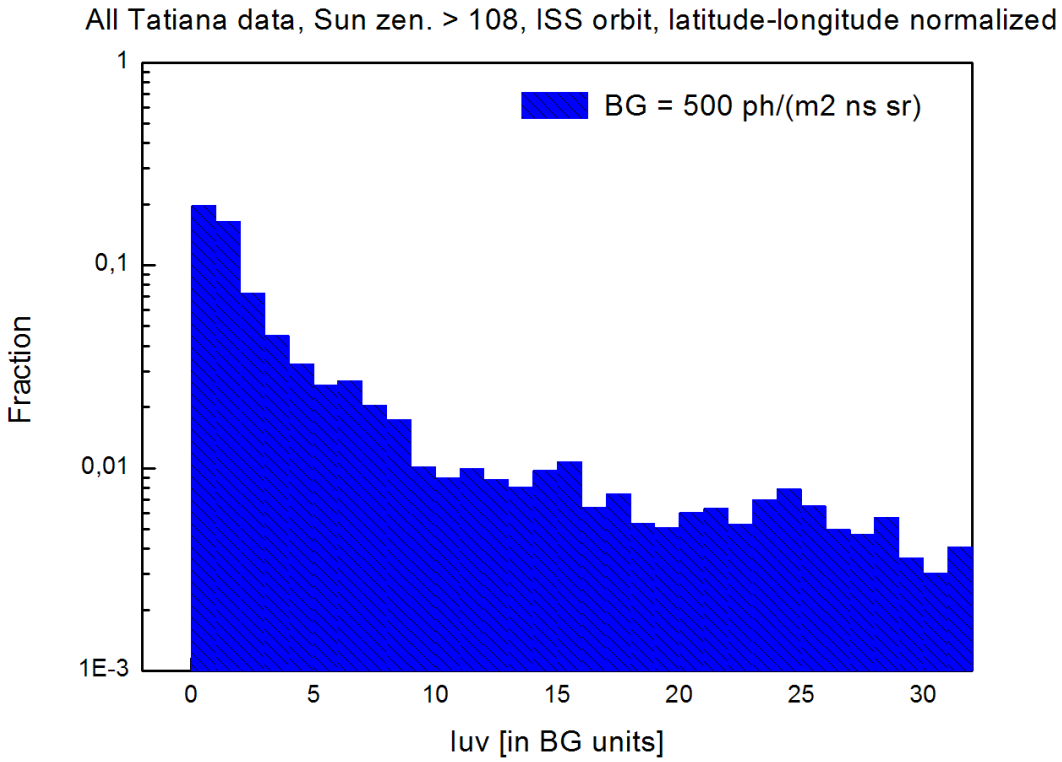
Longitudinal distribution of Tatiana measurements
Sun zenith angle > 108° , D1 data



Distribution of Tatiana measurements in different geo. longitudes

Tatiana measurements are not distributed uniformly in geo. longitudes. Normalization of distribution histogram to this effect is presented on next figure/table.

Sun zenith angle > 108° - ISS trajectory (Tatiana measurements normalized-weighted for latitude and longitude of ISS orbit), D1 data



Sun zenith angle > 108° , ISS trajectory (Tatiana measurements normalised-weighted for latitude and longitude of ISS orbit), , D1 data

BG measurements UV light distribution table

Table 6.

BG in 500 ph/(m^2 s sr)	Coverage [%]	Sum [%]	Rest of hist. [%]
BG x 1	19.6343	19.6343	80.3657
BG x 2	16.4485	36.0828	63.9172
BG x 3	7.3246	43.4074	56.5926
BG x 4	4.4999	47.9073	52.0927
BG x 5	3.2655	51.1728	48.8272
BG x 6	2.5576	53.7304	46.2696
BG x 7	2.7047	56.4351	43.5649
BG x 8	2.0485	58.4836	41.5164
BG x 9	1.7325	60.2161	39.7839
BG x10	1.0173	61.2335	38.7665
BG x11	0.8978	62.1313	37.8687
BG x12	0.9938	63.1250	36.8750
BG x13	0.8757	64.0007	35.9993
BG x14	0.8028	64.8035	35.1965
BG x15	0.9717	65.7752	34.2248
BG x16	1.0755	66.8507	33.1493
BG x17	0.6426	67.4933	32.5067
BG x18	0.7469	68.2402	31.7598
BG x19	0.5366	68.7768	31.2232
BG x20	0.5103	69.2871	30.7129

Average $_{<3xBG}$ = 608.206 ph/(m^2 s sr)

We can conclude (compare Table 1., 2. and 6.) that different orbits and because that different latitudinal and longitudinal distribution of measurements for Tatiana and ISS **has no significant effect** (i.e. less than 1%) to histogram of UV light intensities distribution at values less than 3xBG (1500 ph/(m^2 ns sr)).

Distribution of Tatiana measurements in dependency on Moon zenith angle and moon phase.

Important role in UV lignt measurements on the night side play Moon. Dependency on UV light intensity on Moon phase and Moon zenith angle is presented on the next two figures.

- Sun zenith angle > 108° , ISS trajectory, D1 data

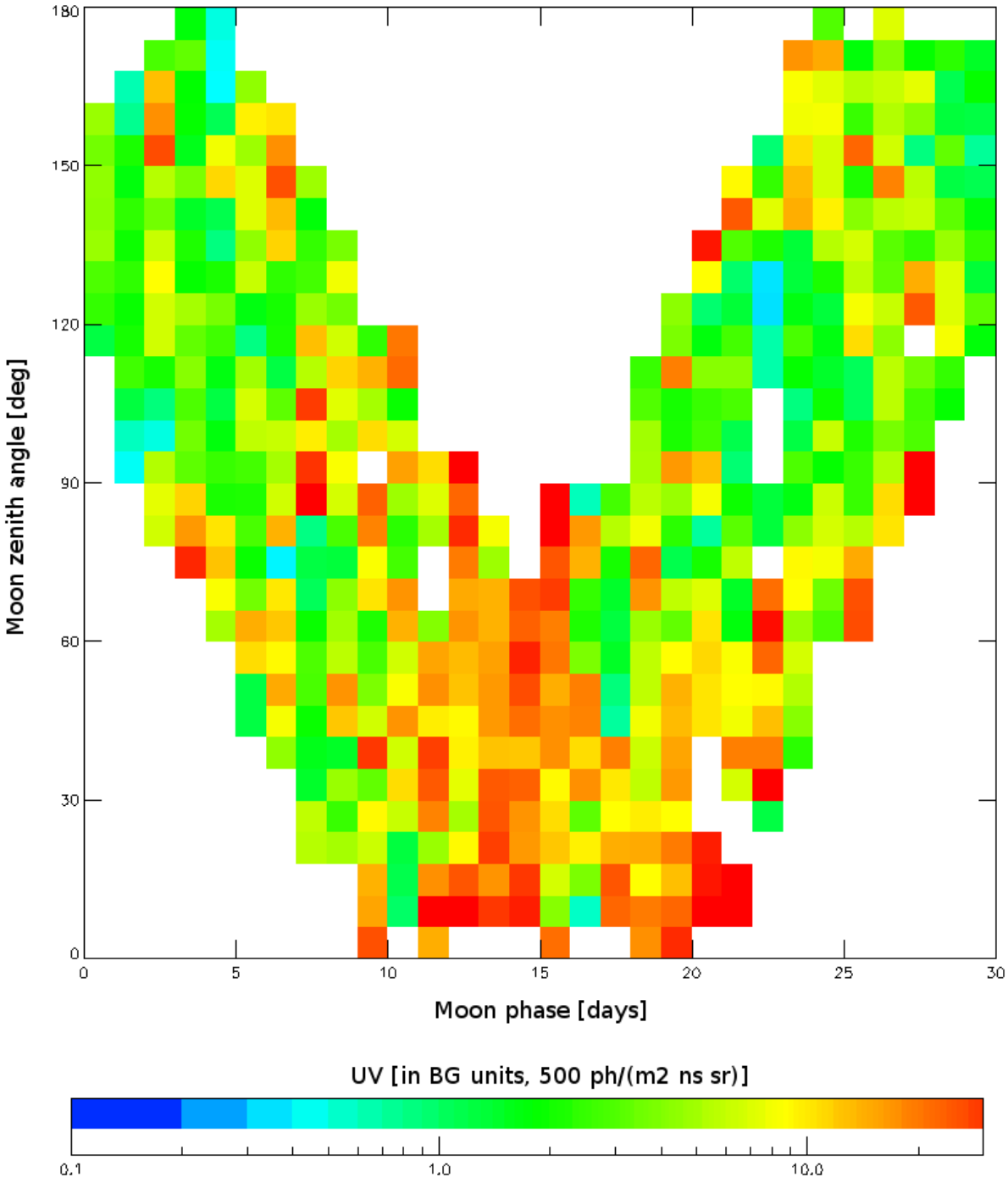


Figure. UV light intensity dependency on Moon zenith angle and phase in Tatiana data (scale-cells 1 day x 6 deg.)

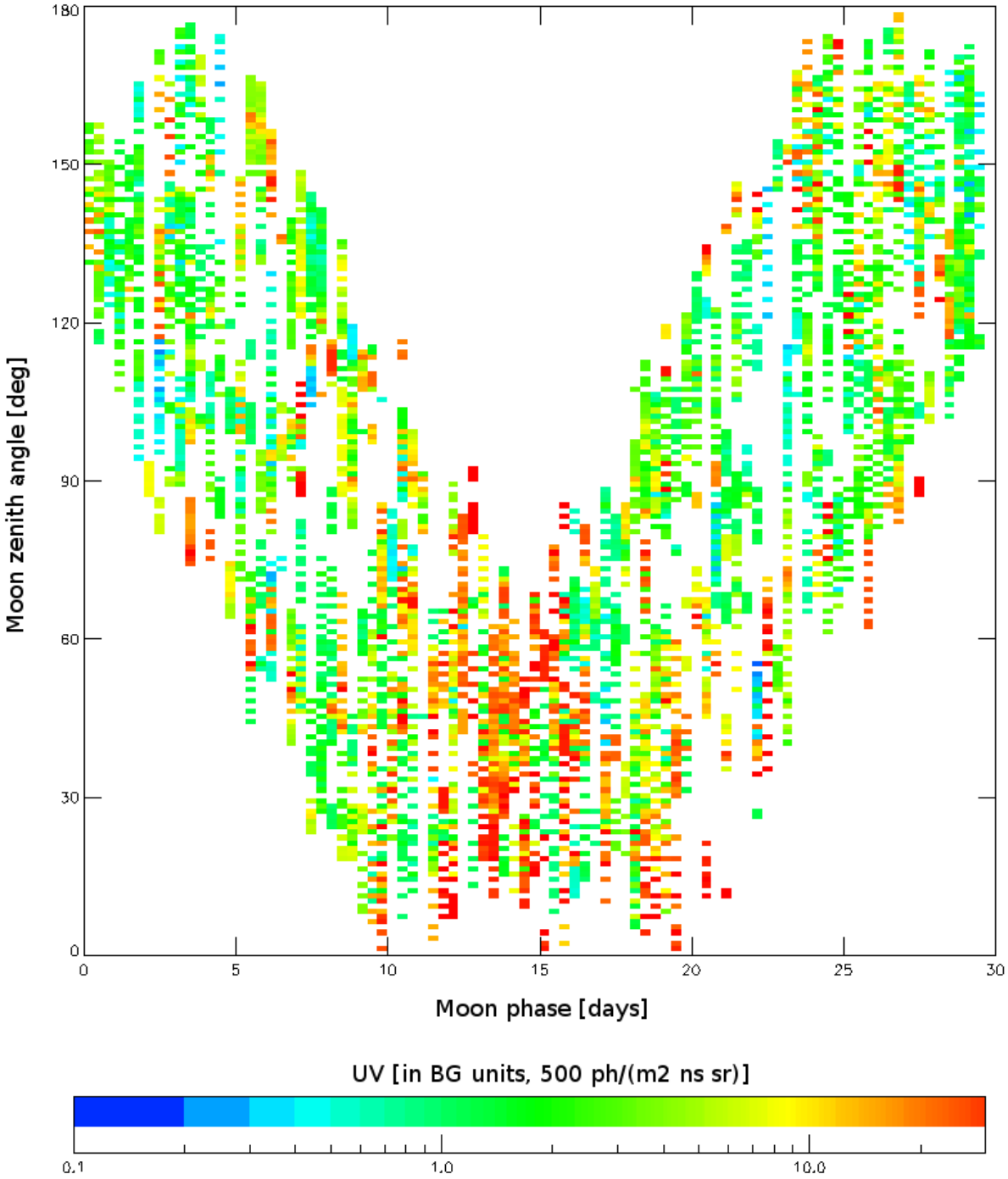
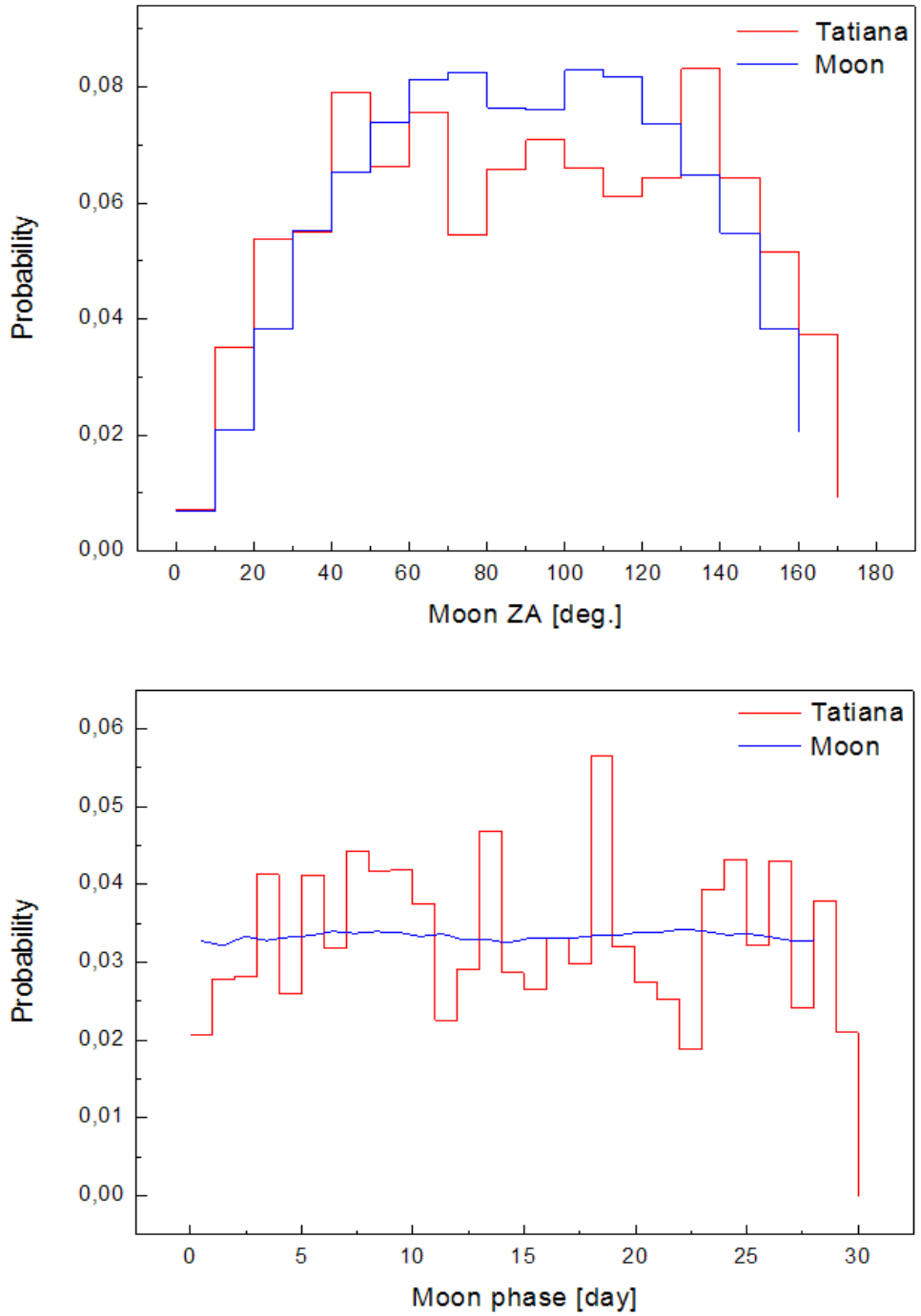


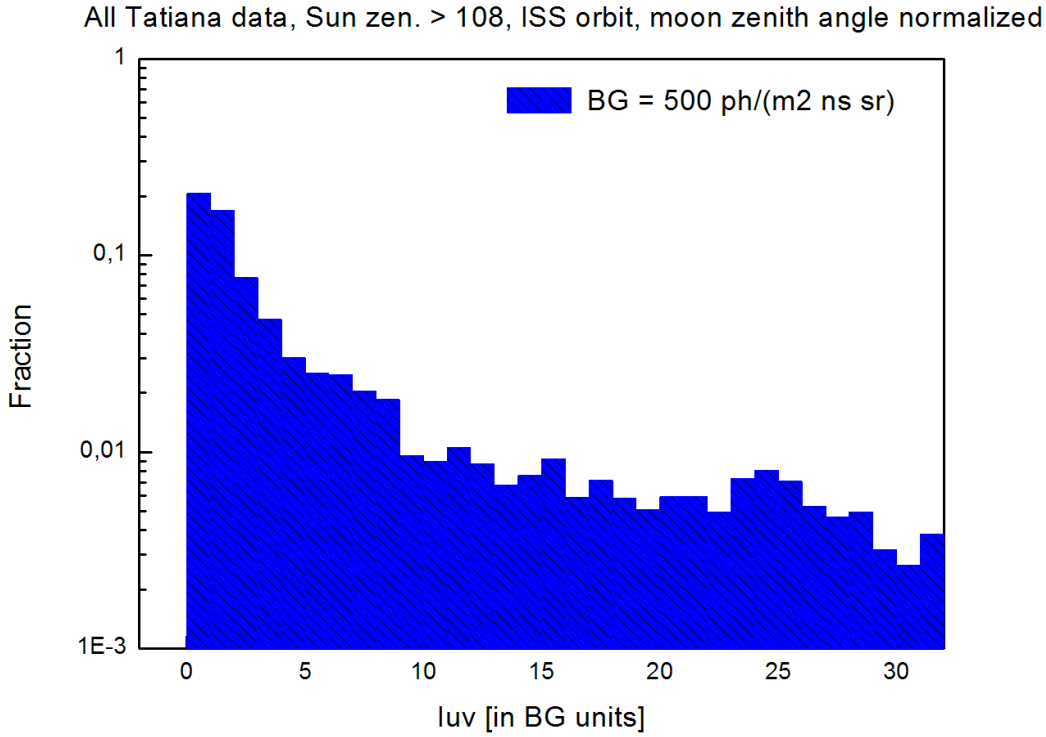
Figure. UV light intensity dependency on Moon zenith angle and phase in Tatiana data (scale-cells 0,33 day x 1 deg.)

Distribution of Tatiana measurement as function of Moon zenith angle (upper panel on the next figure) and Moon phase (bottom panel on the next figure) we compare with simulated distributions of Moon light in JEM-ESUO measurements. As we can see from comparison we need to check if difference between by Tatiana measured and for JEM-ESUO simulated Moon light effect has influence to background estimation for JEM-EUSO duty cycle.



At upper panel: Comparison of Moon ZA distribution in Tatiana measurements (red line) and simulated Moon ZA distribution for JEM-EUSO measurements (blue line).
Bottom panel: Comparison of Moon phase distribution in Tatiana measurements (red line) and simulated Moon phase distribution for JEM-EUSO measurements (blue line).

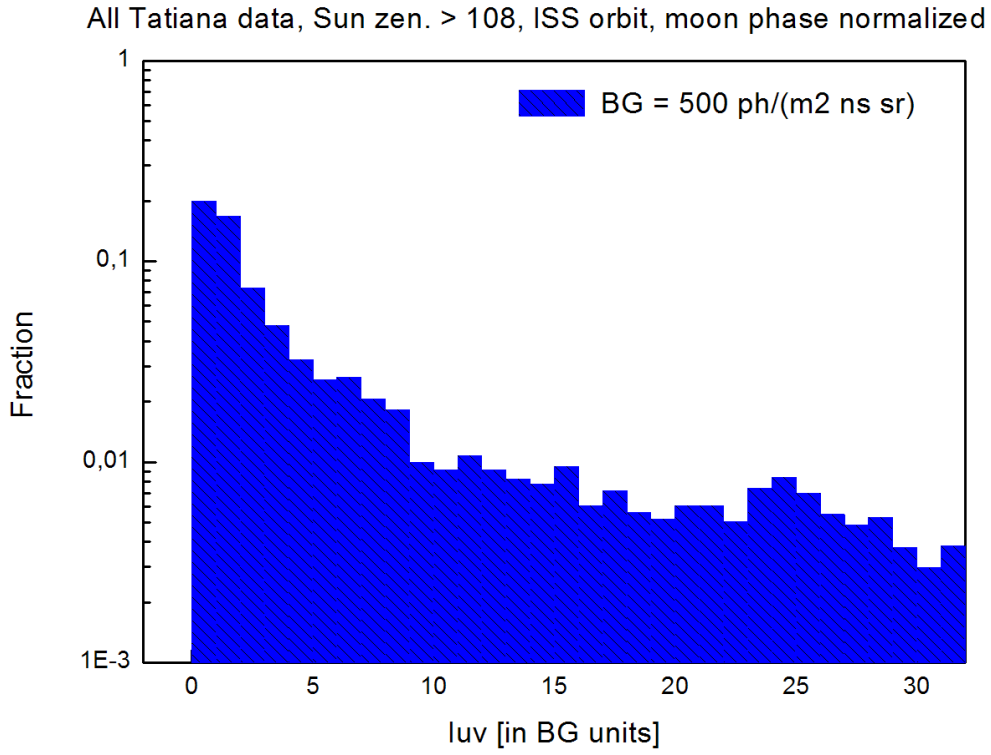
Sun zenith angle > 108° , D1 data
ISS trajectory (Tatiana measurements normalised-weighted for Moon zenith angle)



BG measurements UV light distribution table

BG in 500 ph/(m^2 s sr)	Coverage [%]	Sum [%]	Rest of hist. [%]
BG x 1	20.6349	20.6349	79.3651
BG x 2	16.9254	37.5603	62.4397
BG x 3	7.6836	45.2440	54.7560
BG x 4	4.7281	49.9720	50.0280
BG x 5	3.0149	52.9869	47.0131
BG x 6	2.5148	55.5017	44.4983
BG x 7	2.4733	57.9750	42.0250
BG x 8	2.0495	60.0245	39.9755
BG x 9	1.8506	61.8751	38.1249
BG x10	0.9604	62.8355	37.1645
BG x11	0.8982	63.7337	36.2663
BG x12	1.0509	64.7846	35.2154
BG x13	0.8655	65.6501	34.3499
BG x14	0.6766	66.3266	33.6734
BG x15	0.7581	67.0848	32.9152
BG x16	0.9253	68.0101	31.9899
BG x17	0.5891	68.5992	31.4008
BG x18	0.7157	69.3149	30.6851
BG x19	0.5795	69.8944	30.1056
BG x20	0.5082	70.4027	29.5973

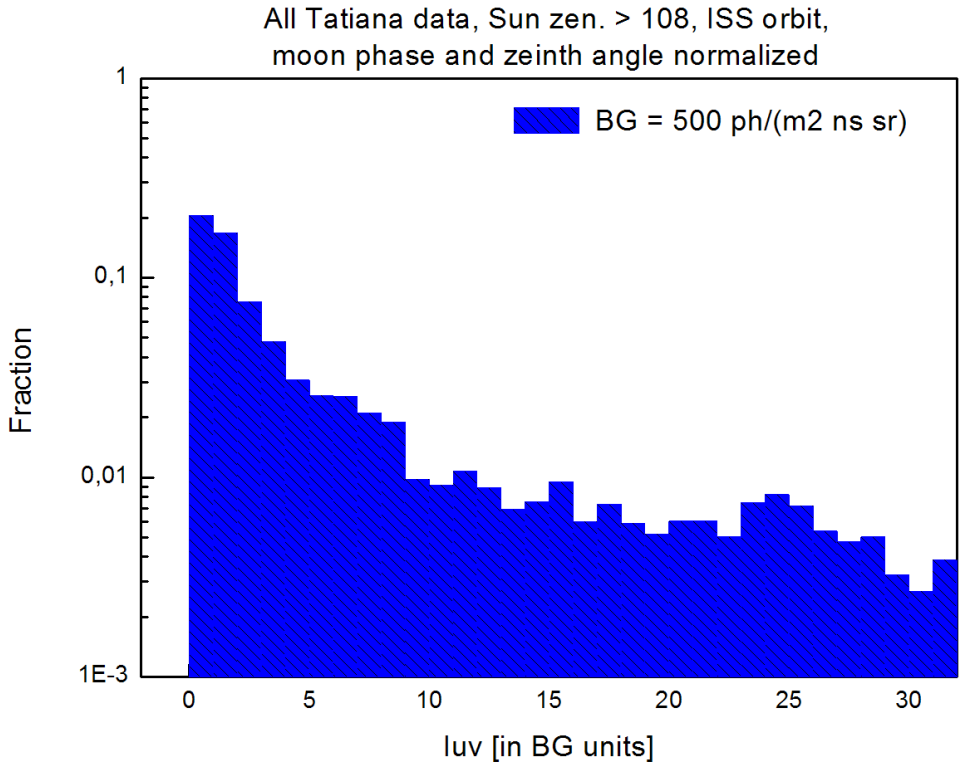
Sun zenith angle > 108° , D1 data
ISS trajectory (Tatiana measurements normalized-weighted for Moon phase)



BG measurements UV light distribution table

BG in 500 ph/(m² s sr)	Coverage [%]	Sum [%]	Rest of hist. [%]
BG x 1	19.9044	19.9044	80.0956
BG x 2	16.6992	36.6036	63.3964
BG x 3	7.3500	43.9536	56.0464
BG x 4	4.8033	48.7570	51.2430
BG x 5	3.2418	51.9988	48.0012
BG x 6	2.5579	54.5567	45.4433
BG x 7	2.6436	57.2003	42.7997
BG x 8	2.0681	59.2684	40.7316
BG x 9	1.8267	61.0952	38.9048
BG x10	0.9947	62.0899	37.9101
BG x11	0.9097	62.9996	37.0004
BG x12	1.0779	64.0775	35.9225
BG x13	0.9100	64.9874	35.0126
BG x14	0.8232	65.8106	34.1894
BG x15	0.7782	66.5888	33.4112
BG x16	0.9525	67.5413	32.4587
BG x17	0.6069	68.1481	31.8519
BG x18	0.7198	68.8679	31.1321
BG x19	0.5585	69.4264	30.5736
BG x20	0.5192	69.9456	30.0544

Sun zenith angle > 108° , ISS trajectory (Tatiana measurements normalised-weighted for Moon phase and zenith angle), D1 data



BG measurements UV light distribution table

BG in 500 ph/(m^2 s sr)	Coverage [%]	Sum [%]	Rest of hist. [%]
BG x 1	20.5623	20.5623	79.4377
BG x 2	16.7148	37.2771	62.7229
BG x 3	7.6087	44.8858	55.1142
BG x 4	4.7881	49.6739	50.3261
BG x 5	3.0725	52.7464	47.2536
BG x 6	2.5743	55.3207	44.6793
BG x 7	2.5335	57.8542	42.1458
BG x 8	2.0941	59.9483	40.0517
BG x 9	1.8890	61.8373	38.1627
BG x10	0.9802	62.8175	37.1825
BG x11	0.9142	63.7317	36.2683
BG x12	1.0708	64.8025	35.1975
BG x13	0.8871	65.6896	34.3104
BG x14	0.6919	66.3815	33.6185
BG x15	0.7543	67.1358	32.8642
BG x16	0.9479	68.0837	31.9163
BG x17	0.6013	68.6850	31.3150
BG x18	0.7306	69.4156	30.5844
BG x19	0.5904	70.0060	29.9940
BG x20	0.5200	70.5259	29.4741